The Journal of HEREDITY

The One With the Transposed Multangulars is Joan

VOLUME 39 MARCH, 1948 NUMBER 3

The

Journal of Heredity

Vol. XXXIX **MARCH, 1948** **No. 3**

CONTENTS

THE NUCLEUS IN DIFFERENTIATION AND DEVELOPMENT, Part II
By C. Leonard Huskins and Lotti M. Steinitz 67

THE BADGET QUADRUPLETS
By J. W. Pryor 79

SIMPLY INHERITED VARIATIONS IN COLEUS
By David C. Rife 85

LINKAGE IN THE HUMAN EYE
By Marianne E. Bernstein and Barbara S. Burks 93

WHITE-BELLIED HOUSE MICE ON SOME NORTH CAROLINA COASTAL ISLANDS
By William L. Engels 94

Reviews and Notes

PUERTO RICO VIGNETTEE (Rev. of PETTULO: *Puerto Rican Paradox*)
By Karl Sax 77

LACK OF CORRELATION BETWEEN COAT COLOR AND TEMPERAMENT 84

GENETICS IS EASY (Rev. of GOLDSTEIN)
By P. W. Whiting 91

GENETICS FOR THE ARTS COURSE STUDENT (Rev. of COLIN: *Elements of Genetics*)
By Clyde E. Keeler 92

SCIENCE CYCLOPEDIA (Rev. of *Von Nostrand's Science Encyclopedia*) 96

— URGENTLY NEEDED—

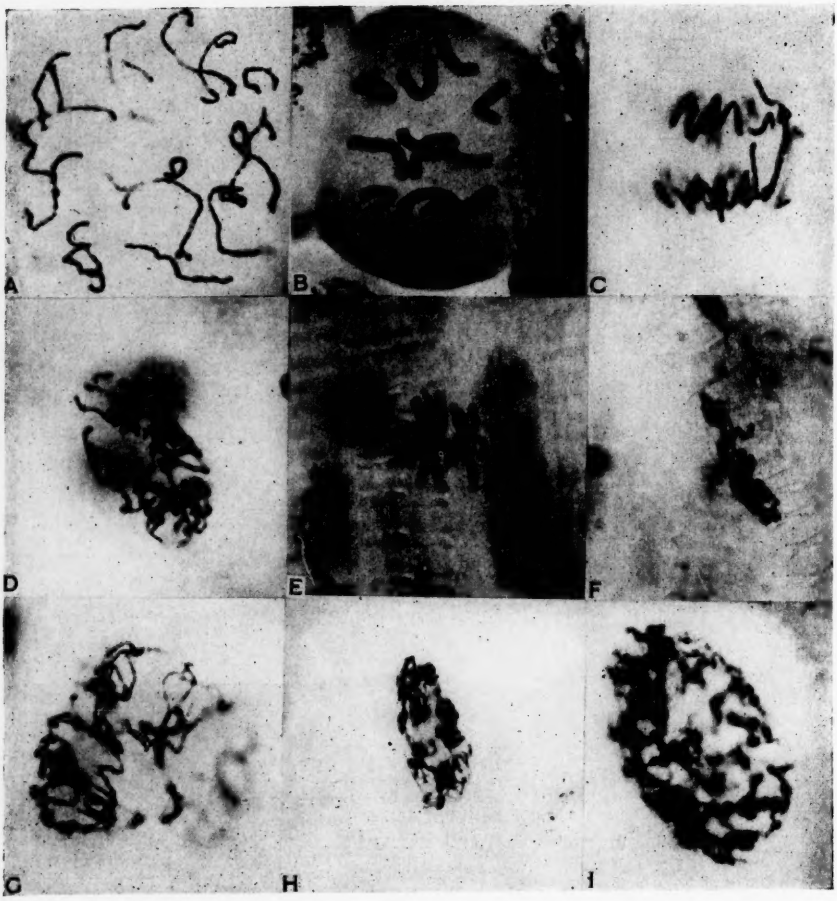
The October 1945 issue of the JOURNAL OF HEREDITY is exhausted.

THIS ISSUE IS URGENTLY NEEDED TO COMPLETE LIBRARY FILES.

Members will confer a favor by returning unwanted copies to us so that war-devastated libraries may be furnished with unbroken series.

WE WILL PAY $1.00 PER COPY FOR THE OCTOBER 1945 ISSUE OF THE JOURNAL OF HEREDITY.

Mail copies to
AMERICAN GENETIC ASSOCIATION
1507 M Street, N. W. ***Washington 5, D. C.***



RELATION BETWEEN DIFFERENTIATION AND CHROMOSOME NUMBER

Figure 1

Mitoses in meristematic and differentiated tissue of *Rhoeo* roots, those in differentiated tissues are induced by stimulation with indole-3-acetic acid. This method causes cell division in nuclei that ordinarily would not divide again. This treatment reveals, but does not produce, the increase in chromosome number observed in the differentiated cells. *A*—Prophase, meristem (1000×); *B*—Metaphase, meristem, showing 12 chromosomes (1250×); *C*—Anaphase, meristem, 1250×; *D*—Diploid, prophase, differentiated region; note differential staining, (1250×); *E*—Diploid metaphase, differentiated region, 1250×; *F*—Diploid anaphase, differentiated region, 770×; *G, H, I*—Polytene prophases, differentiated region; *G*, 1250×; *H* and *I*, 770×. We are indebted to Alfred Owczarzak for much assistance in the preparation of the photomicrographs.

THE NUCLEUS IN DIFFERENTIATION AND DEVELOPMENT

II. Induced Mitoses in Differentiated Tissues of Rhoeo Roots

C. Leonard Huskins and Lotti M. Steinitz*
Department of Botany, University of Wisconsin, Madison

In almost all botany, zoology and genetics textbooks the statement is made, unequivocally, that the chromosome and genic constitution are the same in all cells of a plant or animal body. In advanced treatises and in the minds of research workers this concept may be accepted, generalized or specified and its dual nature may be recognized, or ignored, to very varying degrees.

Though exceptions to the chromosome aspect of this concept had been known at least as early as 1905, "The chromosome number law"† was formulated in 1918 by O. Hertwig[12] as: "The number of chromosomes in all cells of a plant or animal species on occurrence of nuclear division is always exactly the same, whether we are concerned with an epidermis, a cartilage, a muscle, or a gland cell" (translation). Since its formulation, exceptions have continued to accumulate at an increasing rate.

The genic aspect of the concept has necessarily a more indirect and theoretical basis. In 1889 DeVries developed Darwin's "gemmule" concept into the Intracellular Pangenesis Hypothesis. As further developed by Weissman and others this was conceived as a possible mechanism for the localization, in the developing zygote, of nuclear products which could then control differentiation. It was soon found, however, that while no changes could with certainty be determined in the nucleus there were localizations in the cytoplasm, even before fertilization of the egg, that determined various aspects of differentiation. After the genes were definitely known to be located in the chromosomes and it was seen that chromosome constitution commonly appeared to be the same in dividing nuclei of various tissues, it was natural that emphasis was concentrated on the cytoplasm as the seat of differentiation. The fact that segments from very different parts of a plant could reproduce the whole seemed independently to support the concept of genic identity of all cells. Actually, of course, it proves only that the cells which produce the new plants are commonly alike, at least in their potentialities; it tells us nothing of the constitution of cells which do not reproduce.

Schaxel[25,26,27] attempted to show that the evidence from the differentiation of animal eggs was not conclusive; he showed that substances pass out of the nucleus into the cytoplasm during differentiation. The evidence from vegetative reproduction ignores the fact that undifferentiated cells occur throughout a plant and that these may be the source of the new growth. The whole issue is still an open one.[28] E. B. Wilson[30] appraised Schaxel's work very highly but stressed the difficulty of evaluating the significance of his cytological evidence.

*Working under a Fellowship of the American Cancer Society, recommended by the Committee on Growth of the National Research Council.

†It is, of course, unfortunate that the term "law" is applied to any scientific generalization. All our "laws" are concepts. The better ones subsume all the data available at the time they are formulated, but their inadequacies become apparent as more data become available. In one sense, the better a concept the more likely it is to stimulate researches that will lead to its own modification or overthrow.

Now that we have a few more specific stains, ultra-violet and X-ray absorption techniques, the ultra-centrifuge and the electron microscope, further data may be obtainable.

Quite certainly statements such as that of Glaser[8]: "All cells whether they continue to divide or not ultimately contain the same genetic proteins in equal quantities," go beyond the evidence. Berger[2] showed quantitative variations in chromosome constitution of insect tissues. Apparently, however, he places quantitative and qualitative in distinct categories, for later[3] he says: "One of the great generalizations of cytology is that the nuclei of various tissues of any organism have the same chromosome content." He goes on to show that the banding pattern is similar in giant chromosomes from different tissues and says that this "provides evidence for the uniformity of the gene content of different tissues." This latter conclusion has been questioned[13,14] and we also know, of course, that significant differences of form, structure, or kind, may have either a quantitative or qualitative basis.[7] We must consider integrative levels rather than "categories" and shall use "quantitative" and "qualitative" only as operationally useful classifications.

Quantitative Differences Between Nuclei

In the preceding paper of this series[17] evidence was presented from studies of heterochromatic bodies that the energic nuclei of the fourth and fifth mm of *Rhoeo* roots are characteristically polyploid. By such studies Geitler[6] and others have shown that many tissues of insects become polyploid after the cessation of mitoses. White[29] concludes that "The whole process of histological differentiation in insects seems to be intimately bound up with this phenomenon of endopolyploidy, each organ and tissue having its own characteristic degree of ploidy, some being entirely composed of one type of cell, while others are mosaics of cells with different multiples of the fundamental diploid number." The hypothesis on which we are working[13,14] considers polysomaty only as a manifestation of gene activity; the degree of polyploidy or variation thereof is, from this point of view, of very limited significance. Here we shall review only a few especially interesting cases in animals; plant studies will be cited in a subsequent publication.[16]

In flies the nuclei of somatic tissues are ordinarily diploid. In the salivary glands and some other tissues, however, there are giant chromosomes present in the haploid number. Since these arise from the pairing of homologues, it seems at first glance that they conform to the concept of uniformity of chromosome content in all cells. They are, however, multi-stranded or polytene chromosomes and, further, the number of strands apparently varies in nuclei of different sizes, as shown by Bauer.[1]

It was found by Berger,[2] in work that has recently been confirmed and extended by Grell[10,11] that polyteny may be a precursor of polyploidy. In the larval ileum of *Culex pipiens* ($n = 3$) the nuclei of the large epithelial cells undergo mitosis after a long energic growth period. They have three pairs of relationally coiled chromosomes and each member of a pair is a bundle of relationally coiled strands. They separate first into six bundles and then gradually during mitosis the strands of the bundles separate until at telophase there are as many separate chromosomes as there originally were strands. This number varies. In rapidly succeeding mitoses it is reduced until in each nucleus there are only six chromosomes, loosely associated in pairs. We may note especially: 1) Polytene cells are able to undergo mitoses. 2) Polyteny was achieved during the energic stage, as in salivary gland chromosomes of flies. 3) The degree of polyteny varies (the epithelial tissue is "mixoploid"). 4) Polyteny can transform to polyploidy. 5) It can be followed by somatic reduction to diploidy.

Various tissues of the Lubber grasshopper, *Romalia microptera,* were found by Mickey[22] to be mixoploid. He also found multiple numbers in nuclei where

they might be least expected, *viz.*, in the spermatogonia. They were $2n$, $4n$, $16n$, and $32n$. One was $6n$! Primary spermatocytes were $2n$, or $4n$. One was $5n$! Mickey believes that polyploidy has been achieved by reproduction during the energic stage, but he could not rule out incompleted mitosis or nuclear fusion as possible modes of origin. The $5n$ is hard to explain on any commonly accepted concept of chromosome reproduction.

Potter[24] found endomitosis occurring in the differentiation of megakaryocytes from haemocytoblasts in the mouse. They are giant polyploid cells with polymorphous nuclei.

Painter and Reindorp[23] have followed the stages of endomitosis through five cycles in the nurse cells of the ovary of Drosophila. From their increase in volume, the largest nuclei are believed to be 512-ploid, i.e., to have undergone eight endomitotic cycles. In each cycle observed the chromosomes are in bundles; they might therefore be described as polytene rather than polyploid.

Material and Methods

To determine directly the relation to chromosome number of the increase in number of heterochromatic bodies found in the differentiated regions of *Rhoeo* roots,[18] cells in such regions have been stimulated to divide with indole-3-acetic acid. Cuttings and seedlings from which all roots had been removed were placed with their bases in the following culture solution:

	mg/liter	minor elements	mg/liter
$Ca(NO_3)_2 \cdot 4H_2O$	95	Mn	0.5
NH_4NO_3	129	Cl	1.9
$MgSO_4 \cdot 7H_2O$	180	B	0.5
KH_2PO_4	133.5	Cu	0.02
$K_2HPO_4 \cdot 3H_2O$	7.35	Zn	0.01
$Fe_3(C_4H_4O_6) \cdot H_2O$	5.0		

Distilled water was used and the pH adjusted to 5.7. This modification of Hoagland's solution has the advantage of being well buffered.

Each plant was held in position by passing it through a hole in a paraffined cork set in a black glass jar containing 450 cc of the culture solution. They were kept in the greenhouse in full light. During hot weather the temperature of the solution was kept at $22 \pm 2°C$ by placing the jars in a water bath. No sterile culture method was attempted for the present experiment but only healthy, actively growing plants were used. For cytological examination freshly generated roots were used. These varied in length but none was less than 3 cm and none longer than 10 cm. The distal 10 mm of the roots were used for cytological examination. If the roots were growing at a uniform rate, the cells at a certain distance from the tip would always be of the same age. Since there is, however, some variation in growth rate, the shorter roots growing somewhat faster than the longer ones, the factor of variability due to the age of tissues was not fully eliminated.

The plants were transferred for various lengths of time to culture solutions containing various amounts of indole-3-acetic acid, then rinsed with water and replaced in the original solution. Controls were grown continuously in the culture solution, which was replaced about every two weeks. Replications of the most effective treatment were started at different times of day to compensate for possible periodicity in mitosis. None was found.

Slides were prepared by the method described in the preceding paper of this series,[17] except that 10 mm of root were used. In making smear preparations with the aid of a dissecting microscope it is quite easy to remove cortical from stelar tissue with the needles so that on microscopic examination the origin of the cells is apparent even though they cannot be identified more specifically. It is rarely possible to stain chromosomes of differentiated tissues as clearly as those of the meristem.

The following regions of the root can easily be distinguished in either smears or sectioned preparations: 1) The root cap, about 0.2 mm long, has large cells with small nuclei which have a mean of 4.6 heterochromatic bodies. 2) Next there is a region of actively dividing meristematic cells (referred to herein as

meristem); this varies in length with the diameter of the root, being longer in thick roots and extending 1 - 2 mm. 3) Adjoining this is a sharply defined region about 1 mm long where differentiation is in active progress; no divisions occur here in control material and in treated roots they are much less frequent in this than in older regions. 4) The distinctly differentiated tissue, where long phloem cells and annular vessels are present, starts about the 4th mm.

Observations

I. *Meristematic Region*

A. *Controls*

In the meristematic region of control plants only normal diploid divisions occur; they may be described briefly as follows:

Throughout the energic stage heterochromatic regions are visible as irregular, darkly staining bodies.[17] In early prophase the euchromatic parts of the chromosomes that first become visible may or may not be those adjoining the heterochromatic regions (Figures 1*H*, *I*). At a later stage of prophase, when the 12 chromosomes can be distinguished, each is seen to consist of two relationally coiled strands (Figure 1*A*). All kinomeres are submedian; in the longest chromosome, which is 1½ times the length of the shortest, it is almost median. Two chromosomes have pronounced S.A.T.* regions; a single nucleolus is formed. Four other "secondary constrictions" are sometimes visible. As might be expected in a structural heterozygote, none of the chromosomes has an exact mate in the diploid nuclei. At metaphase, Figure 1*B*, the chromosomes are about 1/6 of their length at the time they can first be clearly distinguished. At anaphase some of

*S.A.T. = Sine Acido Thymonucleinico.

TABLE I. Constitution of Dividing Nuclei in Rhoeo Roots after 20 p.p.m. Indole Acetic Acid Treatment for 4 Hours

Hours after treatment	Mm.	No. of roots	*n* p.	*n* m.	*n* a.	2*n* p.	2*n* m.	2*n* a.	2*n* diplo (tetrameric) p.	2*n* diplo (tetrameric) m.	2*n* diplo (tetrameric) a.	4*n* p.	4*n* m.	4*n* a.	4*n* diplo (tetrameric) p.	4*n* diplo (tetrameric) m.	4*n* diplo (tetrameric) a.	5*n* p.	5*n* m.	5*n* a.	8*n* p.	8*n* m.	8*n* a.	Percentage Polyploid	
Controls—see Table II																									
0, 3, 6*	1–2	6	..	..	..	10	7	5	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	
	3	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	4–5	6	..	..	..	2	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	6–7	4	..	..	..	3	4	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	
	8–9	4	..	..	..	3	4	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		0
	10	4	..	..	..	2	4	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
9, 12	1–2	4	..	..	..	66	220	112	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	
	3	4	..	..	..	2	..	..	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	4–5	4	..	..	..	..	3	..	3	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	6–7	5	..	..	..	7	8	2	4	1	..	..	..	..	..	..	..	..	..	..	..	..	..	20	
	8–9	4	..	..	..	14	14	3	2	1	..	2	..	..	..	..	..	..	..	..	..	..	..		18.6
	10	3	..	..	..	9	5	5	3	..	..	1	..	..	..	..	..	..	..	..	..	..	..		
15, 18	1–2	4	..	..	..	32	52	30	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	
	3	4	..	..	..	18	28	28	8	..	..	1	1	2	..	1	..	..	..	..	..	..	..		
	4–5	4	..	..	..	69	82	46	52	2	..	2	12	11	..	..	..	..	..	..	..	..	..		
	6–7	5	..	..	..	45	81	43	68	2	..	6	19	19	..	1	..	..	..	..	..	2	..	33.2	
	8–9	4	..	..	..	35	32	26	45	1	..	2	10	7	..	..	..	..	..	..	..	..	..		50.6
	10	3	..	..	..	4	4	5	2	..	..	..	1	..	..	..	..	..	..	..	..	..	..		
21	1–2	3	..	..	..	24	63	44	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	
	3	3	..	..	..	3	19	2	5	1	..	..	..	..	..	..	..	..	..	..	..	..	..		
	4–5	3	..	..	..	33	62	28	66	16	1?	3	7	1	..	..	..	..	..	..	..	..	..		
	6–7	3	1	..	1	21	52	29	41	5	..	5	17	9	7	..	..	..	2?	..	..	..	..	41.9	
	8–9	2	..	..	..	14	27	19	29	6	..	..	5	..	..	1	..	..	..	..	..	..	..		51.7
	10	2	..	..	..	6	16	18	3	2	..	1	3	..	..	..	..	..	..	..	..	..	..		
24	1–2	4	..	..	..	56	90	78	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	
	3	4	..	..	..	4	10	8	1	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	4–5	4	..	..	..	38	12	8	12	2	..	1	3	4	..	..	..	..	..	..	..	..	..		
	6–7	4	..	..	..	31	25	22	9	2	..	13	4	2	..	..	..	..	..	..	..	..	..	25	
	8–9	4	..	..	..	24	22	13	4	2	..	6	5	..	..	..	..	..	..	..	..	..	..		26.8
	10	3	..	..	..	13	6	7	3	..	..	7	1	..	..	..	..	..	..	..	..	..	..		

*Fixations at successive intervals after treatment are grouped when there is no apparent difference between them.

the chromosomes may assume an S shape instead of the usual V or J (Figure 1*C*). This may mean that some of the secondary constrictions are the seat of secondary kinomeres. Prophases (excluding the very early stages before chromosome number can be determined), metaphases, and anaphases occurred in the ratio 37:40:23 in a sample of 350 nuclei.

B. *20 p.p.m. (parts per million) Indole acetic treatment, 4 hours.*

In the meristematic region divisions were almost completely inhibited for 6 hours following the treatment, after which time they again occurred with normal frequency. At 12 hours after treatment metaphases were somewhat more frequent than in controls and thereafter a slight excess of anaphases appeared, Table I. This increase in the two later phases at the expense of prophases could be due to prophases progressing faster after inhibition. All divisions found in the meristem after this treatment were diploid and no abnormalities of chromosomes or of the distribution mechanism were seen.

C. *50 p.p.m. Indole acetic treatment, 2 hours.*

In the plants treated with 50 p.p.m. for 2 hours, inhibition of meristematic divisions lasted for at least 12 hours, Table II, and even thereafter divisions were less frequent than in the untreated controls. The ratio prophase : metaphase : anaphase was not significantly different from that of the controls ($\chi^2 = 1.32$, $P = 0.5$), indicating that the phase delayed or altered was not one of the division stages but rather the interkinetic phase. It will be seen in Table II that one diploid metaphase with "diplo" chromosomes and two tetraploid metaphases were observed in meristematic tissue 28 hours after the end of the treatment. These could have arisen from interkinetic nuclei in which normal chromosome reproduction occurred but nuclear division was inhibited. No other polyploid or polytene divisions were found in the meristematic regions at any time.

TABLE II. Constitution of Dividing Nuclei in Rhoeo Roots after 50 p.p.m. Indole Acetic Acid Treatment for 2 Hours

Hours after treatment	Mm.	No. of roots	*n* p.	*n* m.	*n* a.	2*n* p.	2*n* m.	2*n* a.	2*n* diplo (tetrameric) p.	2*n* diplo (tetrameric) m.	2*n* diplo (tetrameric) a.	4*n* p.	4*n* m.	4*n* a.	4*n* diplo (tetrameric) p.	4*n* diplo (tetrameric) m.	4*n* diplo (tetrameric) a.	Percentage Polyploid	
Controls	1–2	6	..	..	..	128	139	80	..	..	..	..	..	..	..	..	..	0	
	3	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	4–5	6	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	6–7	4	..	..	..		1	1	..	..	..	..	..	..	..	..	..	0	
	8–9	4	..	..	..	6	4	2	..	..	..	..	..	..	..	..	..		0
	10	4	..	..	..	2	2	2	..	..	..	..	..	..	..	..	..		
0, 3, 6,* 9, 12	1–2	8	..	..	..	4	6	2	..	..	..	..	..	..	..	..	..	0	
	3	8	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	4–5	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	6–7	7	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..	0	
	8–9	6	..	..	..	5	4	2	..	..	..	..	..	..	..	..	..		0
	10	7	..	..	..	2	6	3	..	..	..	..	..	..	..	..	..		
15, 18	1–2	4	..	..	..	23	21	10	..	..	..	..	..	..	..	..	..	0	
	3	4	..	..	..	..	..	1	..	..	..	..	..	..	..	..	..		
	4–5	4	..	..	..	8	6	4	2	..	..	..	..	..	..	..	..		
	6–7	4	..	..	..	6	14	8	..	..	..	1	..	..	..	..	..	4.0	
	8–9	4	..	..	..	20	12	13	..	..	..	..	..	..	..	..	..		4.0
	10	4	..	..	..	11	11	6	..	2	..	..	..	..	..	..	..		
21, 24	1–2	4	..	..	..	37	42	32	..	..	..	..	..	..	..	..	..	0	
	3	3	..	..	..	7	5	10	3	..	..	1	1	..	1	..	..		
	4–5	4	..	..	..	14	26	17	1	..	..	2	..	2	..	..	..		
	6–7	4	..	..	..	37	55	60	5	1	..	3	1	2	..	..	..	12.0	
	8–9	4	..	..	..	22	67	27	13	1	..	4	3	2	..	..	..		12.4
	10	4	..	..	..	20	29	12	7	..	..	2	2	3	..	..	..		
28	1–2	2	..	..	..	36	46	31	..	1	..	..	2	..	..	..	..	2.6	
	3	2	..	..	..	..	..	..	..	..	..	..	..	..	..	..	..		
	4–5	2	..	..	..	14	17	11	8	2	..	5	9	4	..	..	..		
	6–7	2	..	..	..	13	15	11	9	..	..	1	2	5	..	..	..	24.6	
	8–9	2	..	1	..	32	26	18	2	2	..	..	..	1	..	..	..		24.6
	10	1	..	..	..	4	7	1	2	1	..	1	..	1	..	..	..		

*Fixations at successive intervals after treatment are grouped when there is no apparent difference between them.

D. Other treatments

Various lower concentrations of indole-3-acetic acid were used: 0.1 p.p.m., 1 p.p.m., 5p.p.m., and 10 p.p.m. continuously for 7 days; 10 p.p.m. for 4 hours; 20 p.p.m. for 3 and 6 hours. All these treatments produced no abnormalities in the meristematic regions other than temporary inhibition of mitosis; no polytene or polyploid divisions occurred.

II. *Differentiated Tissues*

A. *Controls*

In the differentiated regions of *Rhoeo* roots very few mitoses ordinarily occur. In control plants none was found in the 3rd, 4th, and 5th mm. In the remaining 5 mm that were studied the nuclei of long phloem cells divide occasionally. The mean number of mitoses in the 6th to 10th mm region was 5 per root, Table II. These divisions were always diploid and apparently normal, although due to the elongation of these cells anaphase chromosomes appear to slide past each other as in pollen tube mitoses (Figure 1*F*), rather than to separate from a regular plate.

B. *Indole-3-acetic acid, 20 p.p.m., 4 hours.*

The frequency of mitosis starts to increase in differentiated regions of the root about 6 hours after the end of treatment. A peak is reached at 21 hours after treatment and thereafter the frequency decreases, Table I. Divisions were of greatest frequency in the 5th and 6th mm; fewer were found in the 7th, 8th, and 10th mm but slightly more in the 9th. These peaks may not be significant. Mitotic divisions occurred in all differentiated tissues of the root excepting root hairs. From 60 - 80 per cent were diploid and normal in appearance except where the shape of the cell placed restrictions on anaphase movement. But chromosomes in differentiated tissues frequently stain less intensely with Feulgen and some had regions that stained differentially (Figure 1*D*).

From 10 - 20 per cent of all divisions in the differentiated regions had diplochromosomes.* Such divisions became frequent 12 hours after the end of the treatment and reached their peak 21 hours thereafter; they decreased greatly after 24 hours. If diplo-prophases continue to telophase, a 2*n* diplo gives rise to 2 tetraploid cells and a 4*n* diplo results in two octoploid cells.

In diplo-divisions separation at the kinomere is not synchronous in all chromosomes. They are here classified as diploid-diplo or tetraploid according to the condition of the majority of the chromosomes.

From 3 - 12 per cent of all divisions in differentiated tissues were tetraploid. The frequency of tetraploid metaphases and anaphases was greater than that of tetraploid prophases, as expected since some of them originate from diploid-diplo prophases; their number, however, was not sufficient to account for all the diplo-prophases. It is possible that diplo-prophases take a much longer time before entering metaphase, perhaps longer than the period covered by these experiments. It seems more likely, however, when the low number of diplo-prophases at 24 hours after the end of treatment is considered, that many of the diplo-prophases revert to the energic phase without undergoing mitosis.

Tetraploid divisions become frequent at the same time as diplo-divisions. This, together with the occurrence of the tetraploid number of chromosomes at earliest prophase, indicates that some energic nuclei were already fully tetraploid, not merely diploid-diplo. Ten divisions of the 4*n* diplo type were observed, Table I. Degrees of polyteny that could not be de-

*In a succeeding paper a more comprehensive terminology which seems necessary will be developed. Here that of Levan and others is followed; their diplochromosome will be termed a tetramer. A tetramer consists of four strands which in early prophase are relationally coiled in pairs and again in pairs of pairs. It is single at the kinomere. Between prophase and early anaphase the kinomere divides twice so that at anaphase the 4-stranded chromosome has given rise to 4 normal chromosomes. A diploid-diplo prophase therefore gives rise to 2 tetraploid telophase nuclei. (Figures 2*E, F, G, H.*)

termined precisely are shown in Figures 1*H* and *I*, and 2*D*.

Several exceptional divisions were found in roots 18 and 21 hours after the end of the treatment: Two metaphases in stelar tissue had 30 chromosomes, which is 5*n*; it could not be determined with certainty, however, that each member of the haploid set was present five times (Figures 2*A* and *B*). Two metaphases were found which must be classed as octoploid. They had undoubtedly arisen from 4*n* diplo-prophases. In one of them somatic association of the daughter chromosomes is particularly clear (Figure 2*L*). In the other some of the daughter chromosomes are still relationally coiled but most of them are separated at the kinomere (Figure 2*K*). Two haploid divisions, one at prophase and one at anaphase with six chromosomes moving to each pole, were also found in stelar tissue.

C. *Indole-3-acetic acid treatment, 50 p.p.m., 2 hours.*

Divisions in the differentiated region did not become frequent until 18 hours after the end of this treatment. Most of the divisions (79-96%) then found were diploid. The ratio prophases : metaphases : anaphases did not differ significantly from that in control meristems; evidently no one phase was differentially affected by the treatment.

Divisions were fairly frequent (85 per root in the 4 - 10 mm region) 19 - 24 hours after the end of the treatment but the percentage of polytene or polyploid divisions was only 12.8, Table II. A nucleus that is probably tetraploid-diplo is shown in Figure 1*G*. At 28 hours after the end of the treatment the total frequency of divisions was 121 per root in the 4th - 10th mm and 24.6% of these were polyploid or polytene.

One very unusual metaphase plate was found in the 9th mm of a root 28 hours after the end of the treatment. It looked like a first meiotic division with each of the 6 "pairs" of chromosomes consisting of four distinct strands (Figure 2*I*). Only one "pair" was independent; the remainder formed a catenation, as *Rhoeo* chromosomes do in meiosis. Another "meiotic" division was found in the 10th mm of a root treated with naphthalene acetic.

D. *Other treatments*

With 5 p.p.m. for 40 hours 4 diploid-diplo and 3 tetraploid prophases were found in the cortex near side root initials.

With 10 p.p.m. for 4 hours and 24 hours recovery relatively few divisions occurred in differentiated tissue. Of a total of 69 in the 3rd to 10th mm of 2 roots, 13 per cent were polyploid.

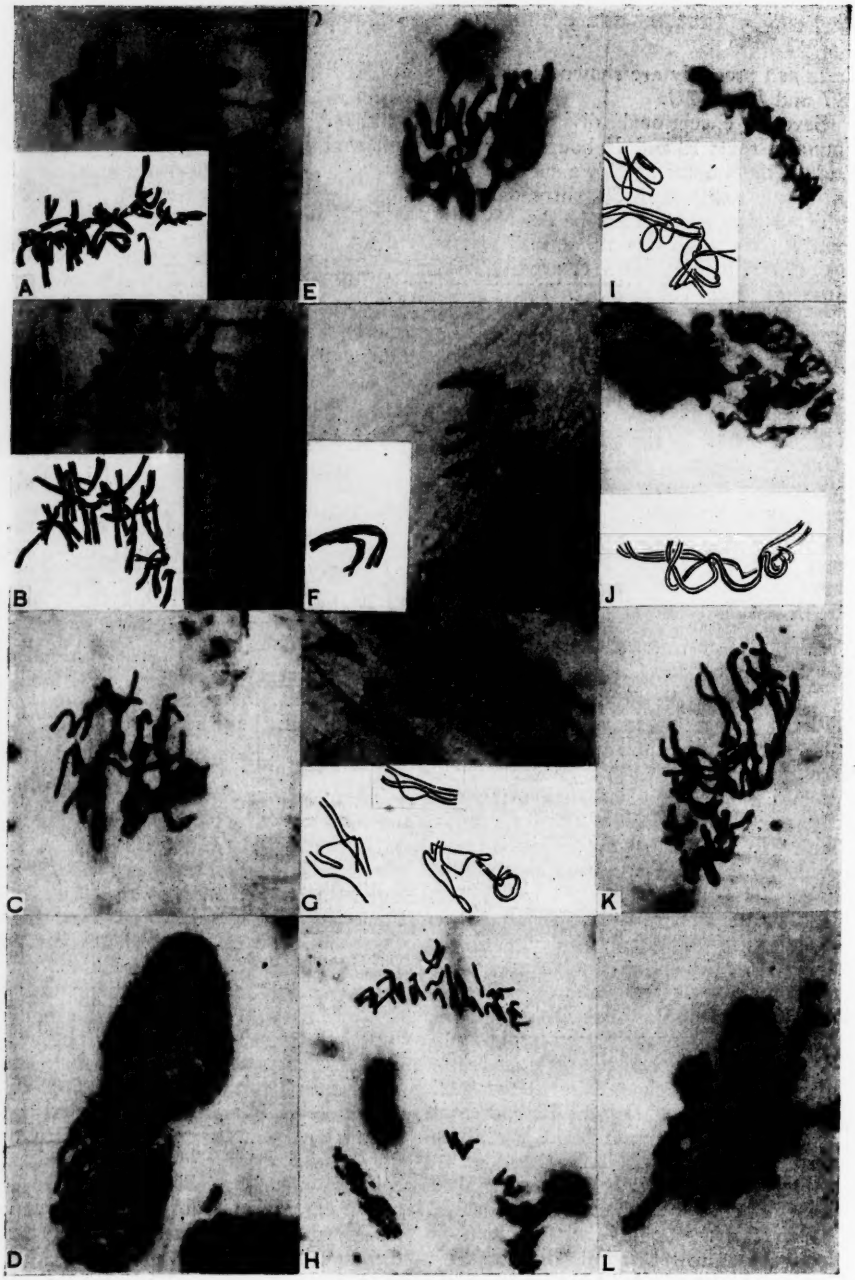
Continuous treatment with 10 p.p.m. for 34 hours induced 108 divisions in the 3-5 mm region of one root. Of these 68 were tetraploid and one octoploid (Figure 2*C*).

A 0.1 p.p.m. treatment was given continuously for 7 days with fixations being made at 30 minutes and at 1, 2, 3, 6, 12, 24, 57, 72, 96, 144, 168, 240, 288 and 336 hours. In none of these fixations was the number of divisions in the differentiated region any higher than in untreated roots. One tetraploid prophase was found in the 6 hour fixation.

Discussion

The possible significance of polysomaty as an accompaniment of differentiation has been considered in detail elsewhere,[13,14] and various aspects have been and will be stressed in other papers of this series.[17,16] Herein we shall consider only the evidence that Indole-3-acetic acid in the 20 p.p.m. for 4 hours treatment merely induces division in nuclei that ordinarily would not divide again and thereby reveals, but does not produce, the changed chromosome numbers.

First, it is clear that the polyploid nuclei have not arisen by "restitution" from abortive mitoses either before or during treatment. There is no visual evidence of any colchicine-like effect or of nuclear fusion. Further, the polytene nature of the chromosomes in many nuclei entering on mitosis proves that their reproduction, in terms of strands, has taken place while they were in the energic stage. There is yet further, though less specific, evidence for this in the fact



INDUCED MITOSES IN DIFFERENTIATED TISSUES

Figure 2

Mitoses induced with indole-3-acetic acid in differentiated root tissue of diploid *Rhoeo*. The insets

that in the differentiated region where numerous divisions occur 18 - 24 hours after treatment, there are extremely few divisions during the entire growth period of these roots (3 - 6 days) before treatment or at any time in the controls. A fourth line of evidence comes from polyploids that arise from wound or callus tissue. Though it is commonly assumed that they have originated through nuclear fusion, this has never been adequately demonstrated. Nuclear fusion does, of course, occur; there is, however, no indication that its frequency is ever anywhere nearly great enough to account, for instance, for the 30 per cent of diploid offspring obtained by Lindstrom and Koos[21] from callus tissue of decapitated haploid tomatoes. "Graft hybrids," once commonly held to be true hybrids resulting from nuclear fusion, have in a great many cases been shown definitely to be chimaeras or mosaics, i.e., fusions of cells or tissues, not of nuclei—which does not, of course, prove that *all* of them are. In any case, nuclear fusion could not explain the origin of pentaploid nuclei, unless the fantastic coincidence of prior reduction to haploidy and duplication to tetraploidy of the nuclei destined to fuse is postulated.

Accepting the evidence that polysomaty originates during the energic stage, we must next consider the more difficult question of whether it occurs naturally or is induced during this stage by the treatments. There are at least 5 lines of evidence: 1) The number of heterochromatic bodies is the same in energic nuclei of the differentiated tissues of control roots as in treated roots, Table III, and it is significantly greater than that of the meristematic region.[17] 2) In the meristematic region, where nuclei are dividing at the maximum rate, the mitotic cycle occupies about 24 hours. Of this period about 3 hours are required for mitosis and 21 hours for the interkinesis during which chromosome reproduction occurs.[9,17] At 12 hours after treatment, diploid-diplo and tetraploid prophases appeared simultaneously. For the treatment to have produced the latter, reproduction during the energic stage would have had to proceed twice as fast as it does in the normal meristem. The same applies to the occurrence of two octoploid nuclei 18 hours after treatment. The occurrence of a tetraploid prophase 6 hours after treatment with 0.1 p.p.m. (which was ineffective in stimulating divisions in general) gives further evidence, as does the entire work of Jähnl[18] and Lauber[20] who found fruit and leaf tissues stimulated to division by simple wounding to be characteristically polyploid. 3) A stronger dosage, 50 p.p.m., does not increase the proportion of polyploid nuclei. 4) The majority of the

TABLE III. Number of Energic Nuclei Containing Various Numbers of Heterochromatic Bodies in the 5th mm of Rhoeo Roots

Number of het. bodies	Controls	20 p.p.m. 4 hrs. + 12 hrs. recovery	20 p.p.m. 4 hrs. + 21 hrs. recovery	10 p.p.m. 34 hrs. (continuous treatment)
10-14	8	1	4	9
15-19	31	7	14	1
20-24	36	8	14	13
25-29	21	4	4	10
30-34	3	1		4
35-39	2			4
Means*	21.3±5.56	21.3±3.2	20.9±.92	23.3±7.8
Percentage of dividing nuclei that are polyploid (cf Table I).				
Observed	0	50%	46%	62.1%
Expected†	14%-100%	50%-100%	60%-85%	14%-100%

*Homogeneity test: P = .95

†This is the range expected on the basis of correspondence between chromosome number and number of heterochromatic bodies if the nuclei stimulated to divide are a random sample; calculated from the Mean plus and minus the Standard Deviation.

on figures *A, B, F, G, I* and *J* are interpretative drawings made on photomicrographs which were then bleached. *A, B*—Pentaploid metaphases. *C*—Octoploid metaphase. *D*—Polytene prophase (lower nucleus). *E*—Prometaphase, intermediate between diplo-diploid and tetraploid. *F*—Metaphase, intermediate between diplo-diploid and tetraploid. Note association of daughter chromosomes. *G*—Early anaphase, intermediate between diplo-diploid and tetraploid. Note four separating chromatids in each chromosome. *H*—Tetraploid anaphase; note association of daughter chromosomes. *I*—"Meiotic" metaphase; the uppermost four-stranded chromosome pair, out of focus, is drawn below. The remaining five pairs are in a catenation, part of which is drawn. *J*—Eight-stranded diploid prophase; lowest chromosome drawn. *K*—Prometaphase, intermediate between diplo-tetraploid and octoploid. *L*—Octoploid metaphase; note association of daughter chromosomes. *A, B, C, D, E, F, G, I, K,* and *L*, 1250×; *H* and *J*, 770×.

divisions in the differentiated regions are still diploid after treatment. 5) The nuclei of the meristematic region all remain diploid excepting for rare cases under conditions wherein the exception may be said to "prove the rule"; e.g. one diploid-diplo and two tetraploid metaphases were found 28 hours after the strong 50 p.p.m. treatment (Table II). In the succeeding paper, polyploid nuclei will be shown to occur under continuous treatment. It has been shown that the treatment inhibits divisions in the meristem and it may therefore have produced these exceptional polyploid cells therein by greatly lengthening the interkinetic period—as it is normally lengthened, though to much greater extent, in the differentiated region. That they appeared only many hours after diploid divisions had been resumed in the meristem is significant in this regard.

The occurrence of two haploid nuclei (Table I), and of a reductional division (Table II, Figure 2*I*), is probably not to be attributed to the treatments. We have found them sporadically in other plants and a number of cases are recorded in the literature. Gates,[5] for instance, reports them in nucellar tissue of *Oenothera,* where the senior author also found several in *Matthiola* (unpublished). Brown[4] has presented a case in cotton which is established both cytologically and genetically. Since our announcement[15] that reductional divisions can be induced by sodium nucleate, many cases of reduction in untreated materials have been reported to us in personal communications. There is also indirect evidence of its probable occurrence in the double reduction of chromosome number found by Kiellander in *Poa*[19] and in other cases of ancestral-type gametes being formed in polyploids.[14] The observations of Berger[2] and Grell[10,11] indicate that it is a normal process in at least one insect tissue. Our evidence from the lower frequency of tetraploid metaphases relative to diploid-diplo prophases indicates that reduction of polyteny may frequently occur. Further evidence will be submitted later in connection with experimental studies of somatic reduction.

Summary

Indole-3-acetic acid has been used to stimulate mitoses in differentiated regions of *Rhoeo* roots, wherein they ordinarily occur only very infrequently. A large proportion of the dividing nuclei are then seen to be polyploid. This parallels the evidence from the number of heterochromatic bodies in untreated nondividing nuclei.[17] Five lines of evidence indicate that the treatments given only stimulate division and do not cause the polysomaty. Two haploid nuclei and one undergoing reduction were found; they were probably not attributable to the treatment. The possible significance of polysomaty as an accompaniment of differentiation is considered elsewhere.[13,14] Whatever the merits or demerits of the hypothesis there presented, the widespread occurrence of polysomaty demands some new concept of nuclear function during differentiation. The occurrence of polysomaty in certain specialized tissues, particularly of insects, has long been recognized; the total evidence now available indicates that it is not confined to any special tissues or organisms but is a very widespread phenomenon. Though differentiation is not, of course, always accompanied by chromosome reproduction, polysomaty and polyteny are evidently in some way associated with differentiation and development.

Literature Cited

1. Bauer, H. *Zeit. Zellf. mikr. Anat.* 23: 280-313. 1935.
2. Berger, C. A. *Carnegie Inst. Wash.* Publ. 469. 1938.
3. ————. *Jour. Hered.* 31:3-4. 1940.
4. Brown, M. *Am. Jour. Bot.* 34:384-388. 1947.
5. Gates, R. R. *Ann. Bot.* 26:993-1010. 1912.
6. Geitler, L. *Chromosoma* 1:1-22. 1939.
7. George, W. H. *The Scientist in Action.* Scientific Book Club, London, 1938.
8. Glaser, O. *Trans. New York Acad. Sci.* Ser. 2, 4:5-22. 1941.

9. GRAY, L. H. Unpublished M.S. 1948.
10. GRELL, M. *Genetics* 31:60-76. 1946.
11. ————. *Genetics* 31:77-94. 1946.
12. HERTWIG, O. *Das Werden der Organismen.* Gustav Fischer, Jena. 1918.
13. HUSKINS, C. L. *Amer. Nat.* 81:401-434. 1947.
14. ————. *Nature* 161:80-83. 1948.
15. ————, *et al. Rec. Gen. Soc. Amer.* 16:38. 1947.
16. ———— and R. LEONARD BENNETT. (In preparation.) 1948.
17. ———— and L. M. STEINITZ. *Jour. Hered.* 39:35-45. 1948.
18. JÄHNL, G. *Chromosoma* 3:48-51. 1947.
19. KIELLANDER, C. I. *Svensk Bot. Tidskr.* 35:321-332. 1941.
20. LAUBER, H. *Öst. Bot. Zeit.* 94:30-60. 1947.
21. LINDSTROM, E. W., and K. KOOS. *Am. Jour. Bot.* 18:398-410. 1931.
22. MICKEY, G. H. *Proc. Louisiana Acad. Sci.* 9:39-57. 1945.
23. PAINTER, T. S., and E. REINDORP. *Chromosoma* 1:276-283. 1939.
24. POTTER, J. S., and E. N. WARD. *Anat. Rec.* 77:77-89. 1940.
25. SCHAXEL, J. *Zool. Jahrb.* 34:381-472. 1912.
26. ————. *Ibid.* 35:527-562. 1913.
27. ————. *Ibid.* 37:131-222. 1914.
28. STERN, C. *Growth Supplement* 19-36. 1940.
29. WHITE, M. J. D. *Animal Cytology and Evolution.* Cambridge Univ. Press. 1945.
30. WILSON, E. B. *The Cell.* Macmillan, New York. 1928.

✦

PUERTO RICO VIGNETTE

THE author presents an interesting sociological analysis of the Puerto Ricans with sympathy and understanding, but contributes little to demography.* Economic and biological problems are considered from an emotional rather than an objective standpoint. According to the author this book "is chiefly concerned with what happens to a people when denied self-government." Yet he later admits that independence now, with the loss of United States subsidies, would be economically disastrous.

When Puerto Rico was discovered in 1493 there were perhaps as many as 30,000 Indians on the island. When the United States acquired the island in 1898 the population was nearly one million. The population now exceeds 2 million, and is growing at a rate which would produce a population of 3 million in 1965. There is only half an acre of cultivated land per person for the present population, with no important industries to absorb the surplus farm population.

The author notes that "starvation, lack of clothing and housing have no adverse effect on the reproductive functions, and medicine keeps the babies from dying." He does not believe that the people will adopt birth control because for the poor Puerto Rican, children are "the only source of joy, security and social esteem." Evidently, he does not agree with Clarence Senior of the University of Puerto Rico, who suggested (JOURNAL OF HEREDITY, May, 1927) that "God gives man both brains and sexual organs. He should use the former at least as frequently as the latter."

The U. S. census of 1940 classified 77 per cent of the population as white — largely of Spanish origin with a trace of Indian. The negroid element is concentrated along the coast. The author concludes that the Puerto Ricans show the vigor of a hybrid people "though it is impossible to tell whether this is due to biological or cultural factors."

The mixture of Spanish culture and Catholic traditions resulted in a society which was "patriarchal, authoritarian, absolutist, semi-feudal." The introduction of American culture led to emotional conflicts which make assimilation difficult. The greatest problem, however, is that of population pressure and the resulting poverty. The author offers no solution.

KARL SAX
Harvard University

*VINCENZO PETTULLO. *Puerto Rican Paradox.* University of Pennsylvania Press. Philadelphia, 1947. $3.00.

THREE-AND-ONE, OR A PAIR AND TWO SINGLETS?

Figure 3

Joyce, Joan, Jeraldine and Jeanette Badgett look more alike every day, and all have the same middle name. In spite of all these similarities authorities are not agreed as to whether the girls arose from two zygotes or three. Are Joyce, Jeraldine and Jeanette identical triplets or is Joyce, like Joan, only a "sister"? Photograph by Rosella Werline.

THE BADGETT QUADRUPLETS

J. W. PRYOR
Laboratory of Anatomy, University of Kentucky

THE question of whether the Badgett quadruplets are derived from two zygotes or three seems not to have been definitely answered by the two contributions published in this JOURNAL.[1,2] Many years of observation have led me to the conviction that the order of ossification of the carpal bones of the hand are determined by genetic factors. Consequently it occurred to me that a comparison of ossification patterns in these children might throw further light on this question of zygosity. The Badgett girls have now reached an age when comparison should yield positive results. I was fortunately able to obtain in 1946 a set of X-ray photographs of their hands. I am indebted to Dr. J. B. Johnson of Galveston, Texas, for furnishing the X-rays shown here.

The Case for Carpal Sequence

Variations in the time of appearance of centers of ossification has been observed in all of the carpal bones except the pisiform. This variation results in quite distinct ossification sequence patterns. Thus the sequence of ossification found in the majority of cases studied is as follows: capitate, hamate, triquetrum, lunate, navicular, lesser multangular, greater multangular. This might be considered *pattern one* in a comparative series.

In a very few instances the hamat will begin ossification in advance of the capitate. The rest of the carpus would follow in regular order, or may show other variation. This would constitute *pattern two*.

The third pattern would be concerned with the triquetrum and its variations, and so on with the other carpal bones. The author published[3] in 1925 the data on which he established sixteen different carpal sequence patterns.

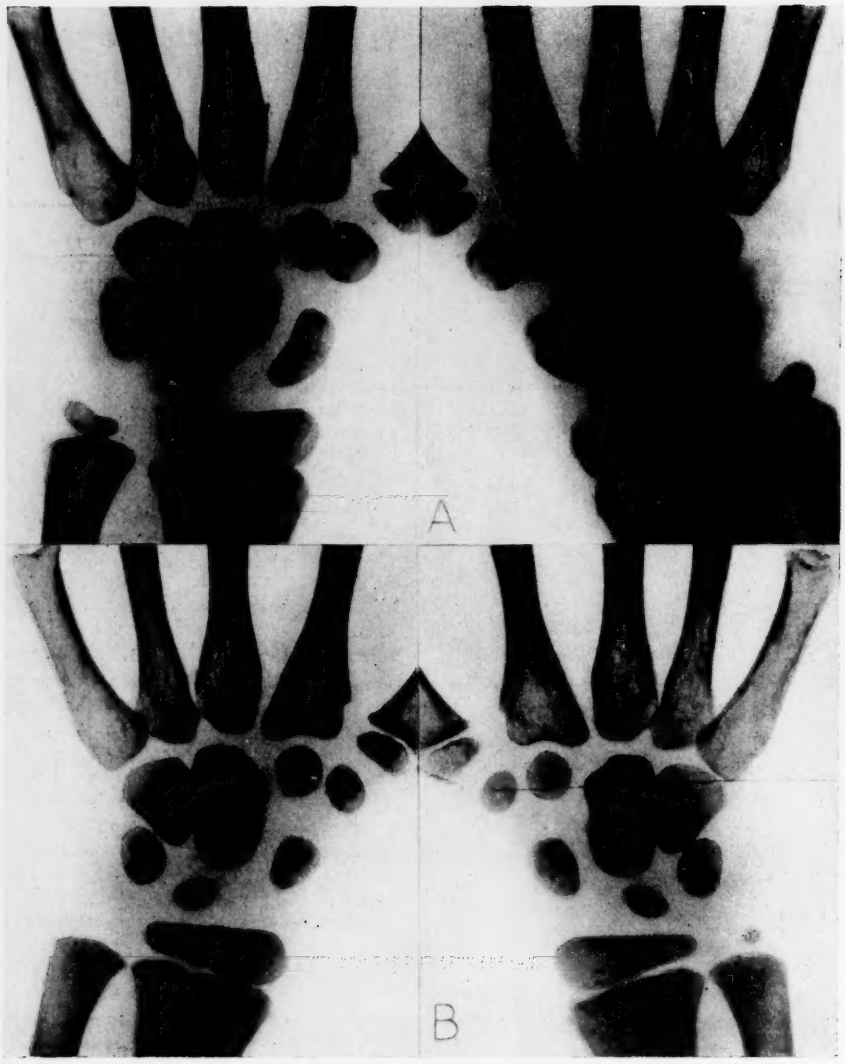
The fact that we find these variations in carpal sequence so often repeated in the same family is to me positive evidence of genetic origin.

In this connection the X-rays of the Badgett quads' hands are very interesting. The hands of Joan (Figure 4*A*), whose fraternal relationship to her sisters is not disputed, shows a carpal sequence quite distinct from her sisters. It is an almost perfect *pattern one,* with the exception that the lesser and greater multangulars are transposed. This is a variation that I have found in a large number of hands. The hands of Jeraldine, Jeanette and Joyce (Figures 4*B*, 5*A*, *B*) all show the same carpal sequence, a very unusual one, namely: capitate, hamate, triquetrum, navicular, lesser multangular, greater multangular, lunate. Note that the lunate is in the seventh position, the usual position being fourth. This is a rare pattern.

The sharp contrast between the carpal sequence of Joan and her three siblings establishes beyond question that Joan is zygotically distinct from her sibs. But does the carpal evidence have an equal force in establishing the fact that the trio developed from the same zygote.? In the absence of other evidence, the concurrence of an unusual carpal sequence such as we have here could be taken as strong substantiation of this view. However carpal sequence does not prove that all three arose from the same chromosome complex. Taken alone, the carpal evidence is not positively diagnostic. As we shall see below, in this series the placental evidence contradicts carpal evidence. The former, in the opinion of the author, if clear-cut, is conclusive.

Other Evidence

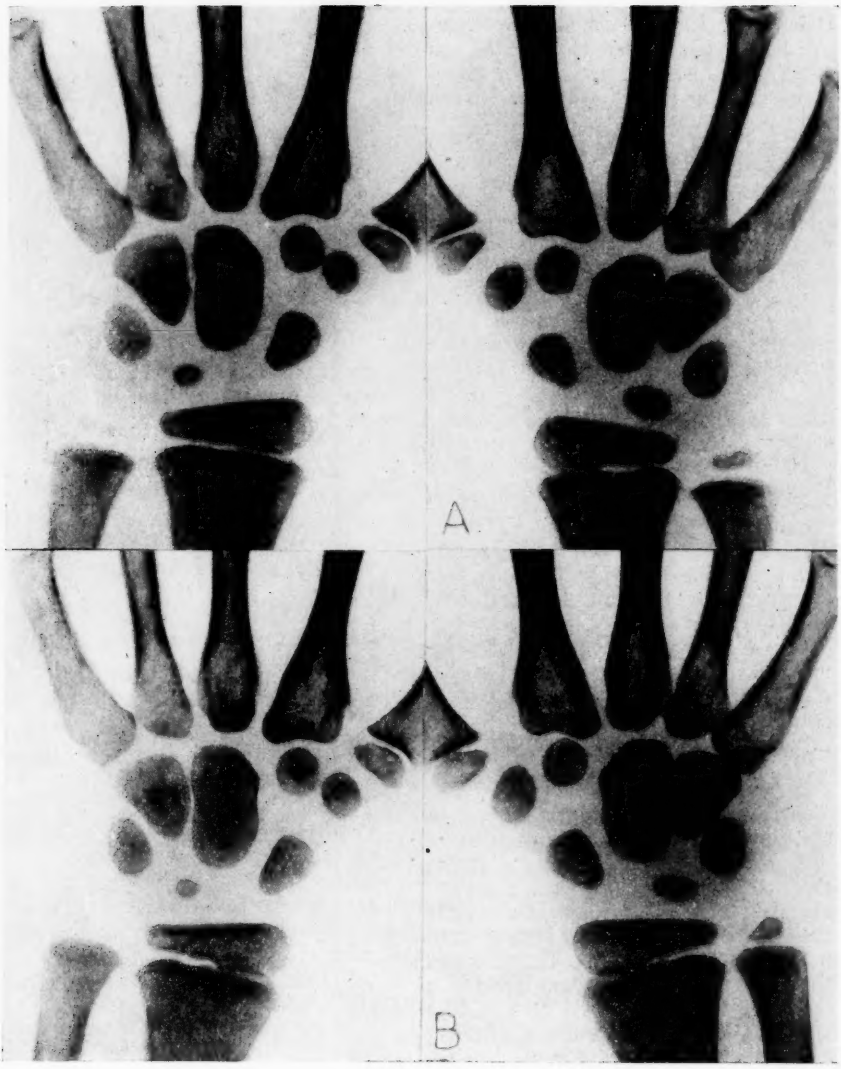
Two other criteria have been applied in an attempt to unravel the zygosity of the Badgett quadruplets: physical resemblance (Figure 3) and fingerprint comparisons (Figure 7). Dr. John G. Sin-



DIFFERENT CARPAL SEQUENCES

Figure 4

The order of carpal ossification differs greatly in different individuals and appears to be an inherited characteristic. On this basis the development of Joan's hands (*A*) supports strongly other evidence that she is "just a sister" to the others, even though she happened to be born at the same time. Her carpel ossification sequence is the popular pattern: capitate, hamate, triquetrum, lunate, navicular, greater multangular, lesser multangular. Jeraldine (*B*) and the other two girls (Figure 5) all show the same unusual sequence: capitate, hamate, triquetrum, navicular, lesser multangular, greater multangular, lunate. See Figure 6 for a sketch-map of these bones. bones.



SIMILAR PATTERNS

Figure 5

Jeanette (*A*) and Joyce (*B*) have the same ossification pattern as Jeraldine (Figure 4*B*). Note also the great similarity in ossification of the epiphyses on the ends of the long bones, in contrast to Joan. The pattern displayed by three of the twins is very unusual, and their similarity in this respect might be interpreted as evidence that they are monozygous. In the author's opinion, the placental evidence outweighs this concordance as evidence that Joyce is isozygous with the admittedly identical Jeanette and Jeraldine.

clair, Professor of Histology and Embryology at the University of Texas, has supplied me with fingerprints, a group photograph, and additional data. He has written me as follows:

December 26, 1946. The photograph shows remarkable similarity in all of them, even more than was present at birth. Since Joan was from a separate placenta and was quite different in weight and appearance it indicates the danger of using similarity alone as a test of monozygosity. I have seen successive children of one family show practically identical pictures when taken at the same age.

January 2, 1947. So far as external appearance goes the girls look more alike now than they did at birth or at one year. That is rather remarkable because Joan definitely is not genetically identical either by placental nor dermatoglyphic evidence. It again raises the question whether mere resemblance is sufficient evidence of homozygosity or identical twinning.

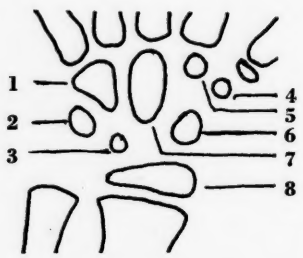
Physical resemblance, then, neither proves or disproves anything. The fingerprints are scarcely more useful to our purpose. The fingerprints of all four are practically the same; even that of Joan is very much like the others.

One other consideration may be significant. The sequence of birth—Jeraldine, Jeanette, Joyce, Joan—may mean nothing, and again it may be important evidence in the light of other facts.

The Placental Evidence

Dr. Sinclair has described the placenta and published a photograph of it in an earlier article.[1] "The placenta shows three cords, marginally placed, one-third of this placenta had its own chorionic vesicle and the two-thirds have a common vesicle. An injection demonstrates that the latter have common circulation by several large superficial vessels. The third is firmly grown to the other along a scar line that is composed of decidua. Only a single small vessel passed across the scar line, probably as a secondary anastomosis."

I have seen a number of cases that I thought were fused placentae. They were similar to the placenta figured by Dr. Sinclair. If these two sections were originally separate placentae they were the product of two zygotes. It would seem to me this is evidence that the Badgett quads are trizygotic in origin.



THE SEVEN CARPALS
Figure 6

The most frequent ossification sequence begins with the capitate, but many other sequences are found in studies of large populations of children. 1. Hamate; 2. Triquetrum; 3. Lunate; 4. Greater Multangular; 5. Lesser Multangular; 6. Navicular; 7. Capitate; 8. Radial Epiphysis.

Gardner and Newman[2] described the afterbirth as follows:

The afterbirth consists of two distinct placentae. The smaller one simple, the larger doubly compound.

We know that Joan was attached to the smaller placenta and was doubtless derived from a single zygote.

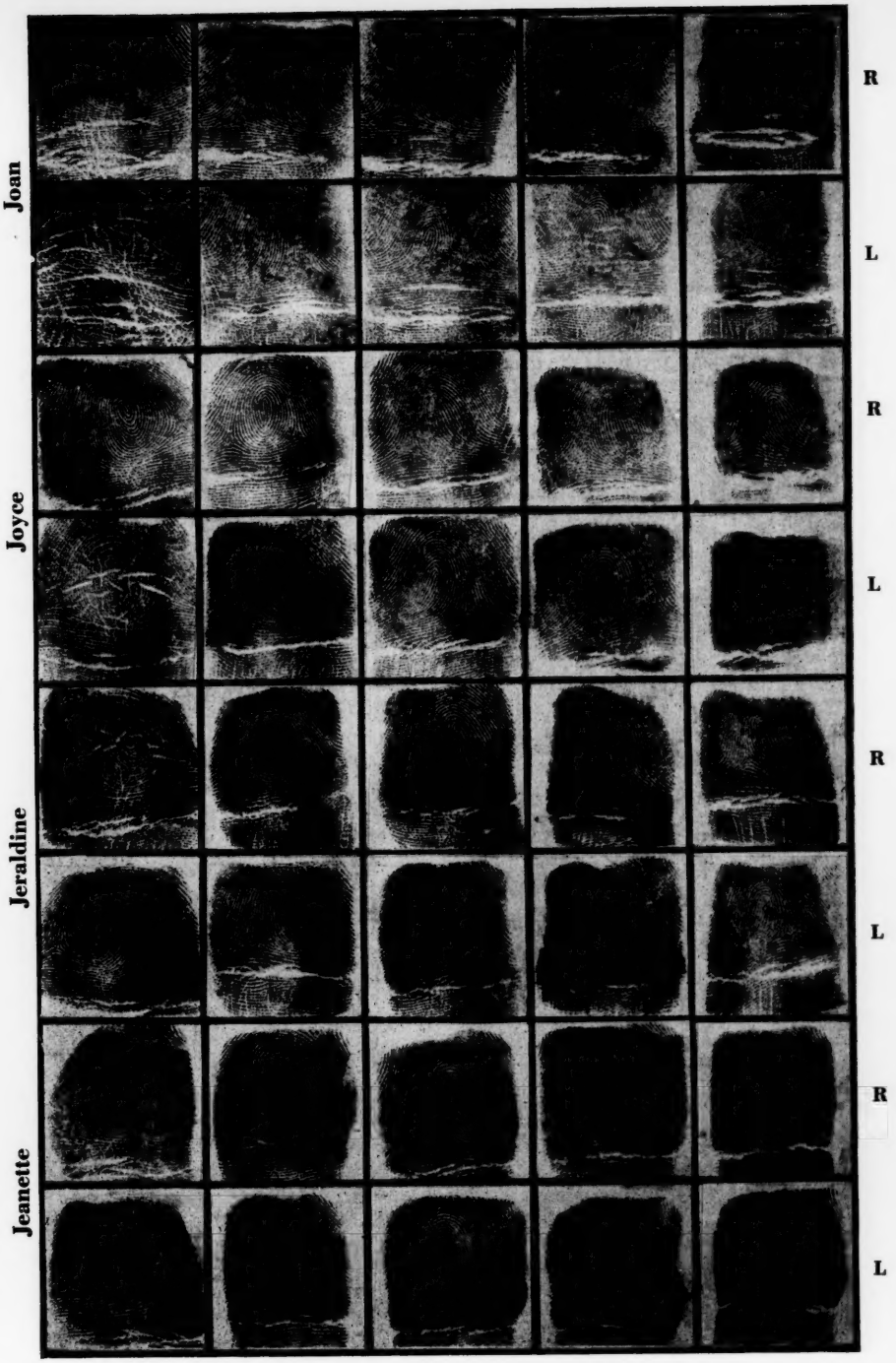
The larger placenta possessed two chorionic membranes, but there was no evidence that this placenta was the product of fusing of two originally separate smaller placenta. One of these chorionic membranes contained one fetus and the other two fetuses, each with its own amniotic membrane.

These are facts that would make one think sequence of birth had some significance: Jeraldine, Jaenette in the same chorion, Joyce from the chorion of the small section, and Joan of the distinctly separate placenta.

Conclusions

Five factors have been considered in an effort to shed light on the exact degree of zygosity of the Badgett quadruplets: carpal sequence, physical resemblance, fingerprints, birth order, and the placental evidence.

Physical resemblance, never an accurate index, in this case clarifies nothing. Carpal sequence, fingerprints, and birth order, in greater or lesser degree cor-



FINGERPRINT PATTERNS—ENLARGED

Figure 7

roborate the fact that Joan is zygotically distinct from her sisters. Further, although carpal sequence and the fingerprints tend to support the dizygotic theory, they cannot be considered as diagnostically positive.

The appearance and description of the placenta gives me the impression that there has been a fusion of two placentae, due to proximity of implantation and pressure. On this view, it is the product of two zygotes; hence the quads are trizygotic.

I have reviewed the evidence without prejudice and I am forced to the conclusion that the Badgett quadruplets are trizygotic, Jeraldine and Jaenette being identical twins, Joan and Joyce being fraternals.

Literature Cited

1. Sinclair, J. G. *J. Hered.* 31:163. 1940.
2. Newman, H. H., and I. C. Gardner. *J. Hered.* 33:345. 1942.
3. Pryor, J. W. *Am. J. Phy. Anthrop.* Oct.-Dec., 1925.
4. ————. *J. Hered.* 30:249-255. 1939.

✦

Lack of Correlation Between Coat Color and Temperament

To the Editor:

The article entitled "Coat Color, Physique, and Temperament" by Clyde E. Keeler in the September 1947, issue of the Journal of Heredity interested me very much. So much so that I spent several hours compiling data which resulted in the table shown below.

For a master's degree in psychology at the University of Kentucky, I constructed a rating scale of temperament for thoroughbred brood mares. I will use the rating scale as part of my doctoral dissertation.

After selecting one hundred twenty-four (124) mares rated as to temperament or disposition and classified in the following three groups, e.g., high-spirited, intermediate, and phlegmatic, I tabulated the coat colors for these three groups. The results may be seen in the table. The mares were chosen at random from eight breeding farms here at Lexington.

TABLE I. Thoroughbred Brood Mares Classified as to Temperament and Coat Color

	Chestnut	Bay	Bay or Brown	Brown	Brown or Black	Black	Totals
High-Spirited	11	15	4	8	2	2	42
Intermediate	12	24	0	5	0	0	41
Phlegmatic	8	23	2	7	0	1	41
Totals	31	62	6	20	2	3	124

While the number of mares used in this study is small, it is at least suggestive that there is no significant relation between temperament and coat color.

(Mrs. J. A.) Betsy Worth Estes
215 Irvine Road
Lexington, Kentucky

SIMPLY INHERITED VARIATIONS IN COLEUS

A Résumé

DAVID C. RIFE*

CULTIVATED coleus varieties are characterized by a profusion of variations in color and shape of leaves. Many of these are simply inherited, and have been discussed in scientific journals. It is our purpose here to describe some variations not previously reported, as well as briefly to review others recorded in greater detail elsewhere.

Leaf Color

1. Six multiple alleles, designated as the purple series, affect the amount and distribution of anthocyanin[2,7]. Their interactions result in the following nine phenotypic variations: Uneven purple (P^LP^L, P^Lp, P^Lp^{-m}); even purple (PP, Pp, Pp^{-m}); black (P^LP); brown (P^Lp^S, Pp^S); gray (P^Lp^G, Pp^G); green (p^Gp^G, p^Sp^S, p^Gp^S, p^Gp, p^Gp^{-m}, $p^{-m}p^{-m}$); spotted (p^Sp); pattern (pp); and semi-pattern (pp^{-m}). Uneven purple plants are also characterized by dark blue flowers and spotted stems.

2. A dominant gene (B) results in leaves having solid purple lower epidermis[6]. Its recessive allele has no effect on color. This pair of alleles is independent of the purple series.

3. A tan plant appeared among the progeny of a solid green plant from a pure breeding green strain. Evidently this was a new mutation, for when selfed it gave progeny in the ratio of 1 green (nn), 2 tan (Nn), and 1 purple (NN). This variation has not been previously described.

4. Boye[2] reported that characteristic dark splotches on the upper leaf surface are due to a simple dominant gene (S). This is distinct from the spotting of the purple series.

5. Faint pattern, as contrasted with distinct, appears to be due to a dominant gene (O)[6].

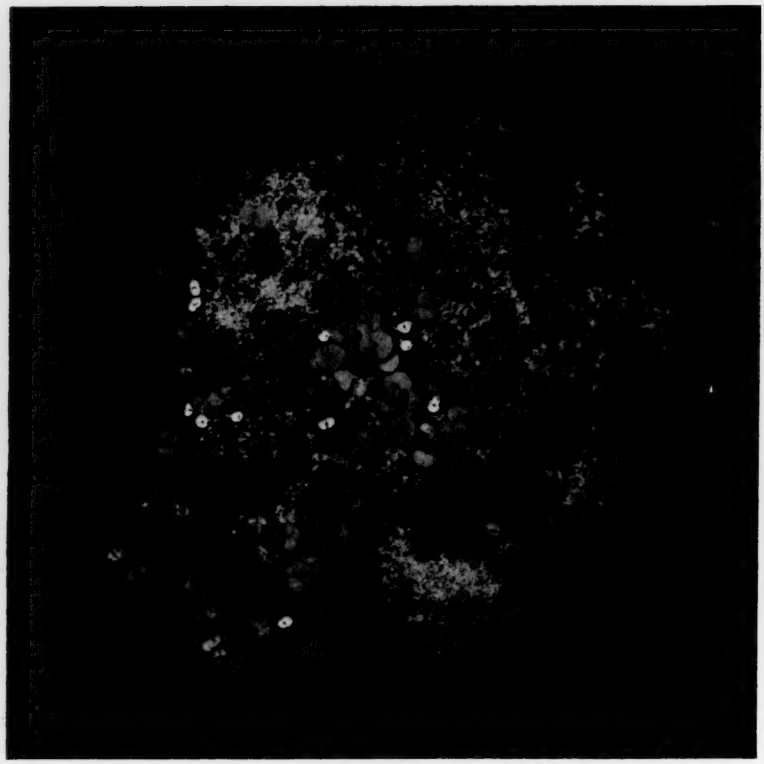
6. Lack of chlorophyll in the middle of the leaf (sometimes called "albino midrib") is due to a recessive gene (a_1a_1)[6]. This variation is found in many of our most colorful strains. Anthocyanin in combination with dark green (p^Gp^G, etc.) results in brown, and with white gives pink. Trailing Queen, a favorite among coleus growers, is homozygous for pattern (pp) and for a_1a_1. Leaves of this variety have four colors, green along the outer margin, white at the base, pink in the center, with a zone of brown between the outside green and the central pink (See Figure 9*A*). Solid green leaves differ from the strikingly patterned Trailing Queen leaves in only two pairs of factors.

7. A certain clone when selfed regularly produces offspring in the ratio of three green to one white (albino). (See Figure 8). The latter soon cease growing and die. We see here the operation of a recessive gene lethal when homozygous (a_2a_2).

8. Leaves may be either intense dark or dilute yellowish green. Intense (I) is dominant to dilute green[3]. Anthocyanin over dilute green produces scarlet, as contrasted with brown resulting from anthocyanin over intense green. Patterns on dilute green leaves give scarlet centers and golden margins, an attractive combination.

9. Coleus may have either red or green stems and veins. Red appears to be conditioned by a dominant gene (V), although further investigation is needed here.

*Genetic Studies of Coleus No. VII. Departments of Zoology and Botany, Ohio State University.



ALBINO SEEDLINGS

Figure 8

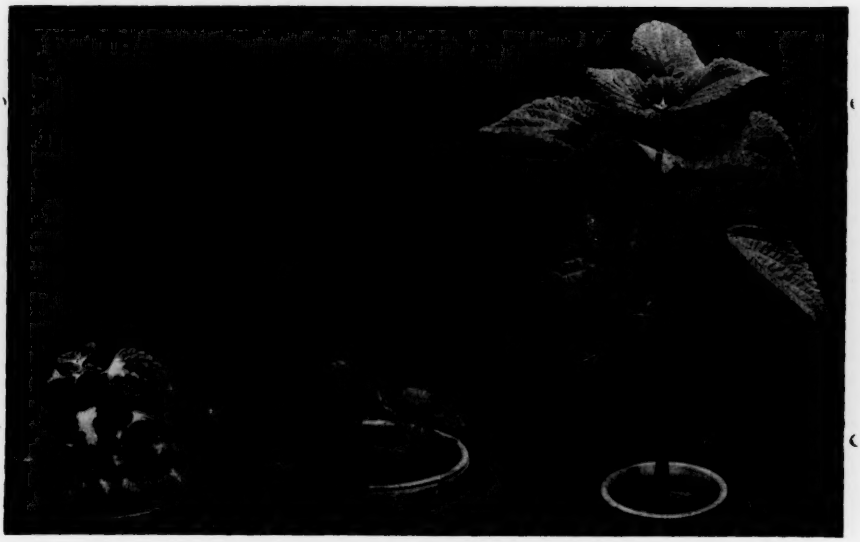
Seedlings showing segregation of green and complete albinism. Note the smaller size of the albinos. They do not grow after emergence and soon die. Albinism is conditioned by a recessive gene.

Leaf Shape

1. Crinkly leaf has been reported[5] as being due to a dominant gene. This appears to be similar to a condition reported by Post[4] which she termed "ruffled". She found it to be due to a relatively unstable dominant gene, and observed one non-ruffled plant with a ruffled branch, and a ruffled plant with a non-ruffled branch. Later investigations have suggested to us that the peculiar appearance of crinkly leaves is due to a virus, to which some plants are immune and others susceptible, the latter condition resulting from a dominant gene (*C*).

2. Some plants are characterized by leaves with shallow lobes, and others by deep lobes. Deep lobes are dominant over shallow. At least three multiple alleles appear to be concerned (*L*, l^p, *l*), only one of which results in shallow lobes. Deep lobes are characterized by variable expressivity, whereas shallow lobes are quite constant.

3. Irregular leaf shape is dominant (*G*) to regular leaf shape (*g*). (See Figure 11). Plants of this type have been classed as a different species (*C.*



QUEEN'S POLYPLOID PROGENY

Figure 9

The plant on left is of the Trailing Queen variety; in the center, a polyploid resulting from a cross between Trailing Queen and a gray plant; on the right, a plant of the purple variety.

lacineatus), but they actually differ from regular leafed plants in only this one allele[8].

4. Plants possessing the genotype both for deep lobes (*L*–) and for irregular leaves (*G*–) present a very unusal appearance. (See Figure 11*D*). Acting on a suggestion of Dr. D. F. Jones, we have labelled these "watermelon leaves." We have here a situation analogous to comb shape in chickens, wherein two independently inherited pairs of alleles interact on a single trait in such a manner as to result in four distinct phenotypes. (See Table I.)

Male Sterility

All of the deep-lobed plants in the original strain with which we worked were male-sterile. In subsequent crosses with shallow lobed fertile male plants, the offspring invariably consisted of approximately equal numbers of deep lobed male-sterile plants and of shallow lobed male-fertile plants indicating close linkage between the genes for male sterility (*D*) and deep lobes (*L*). More recently we have found two strains of plants, both of which are deep lobed and male fertile. We have yet to find a shallow lobed male-sterile plant.

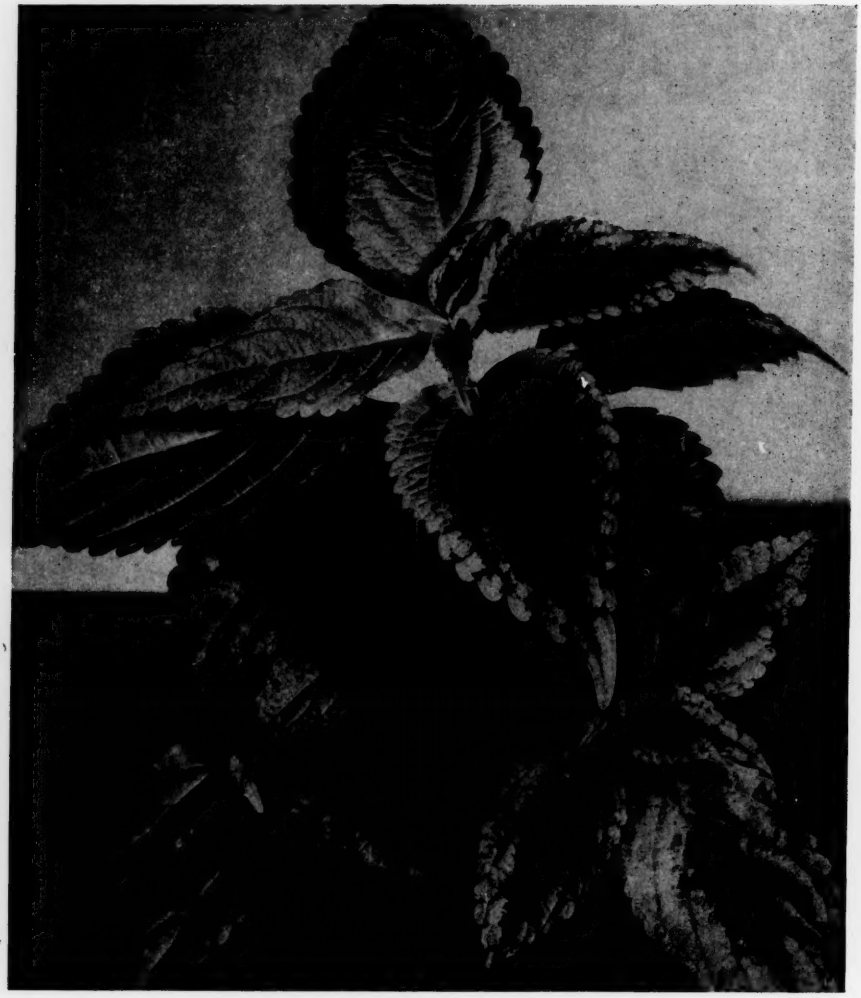
Chimeras

Some strains of coleus produce chimeras rather frequently. These affect both the distribution of anthocyanin and of chlorophyll. Figure 10 shows a plant with patterned leaves on one side and solid green on the other. Cuttings were made from both solid green

TABLE I. Results of crossing plants with irregular deep leaves *(GgLl)* × plants with regular shallow lobed leaves *(ggll)*.

Class	Observed	Calculated	χ^2
Irregular deep	45	42.55	0.188
Irregular shallow	48	42.25	0.782
Regular deep	45	42.25	0.188
Regular shallow	31	42.25	2.995
Total	169	169	4.153

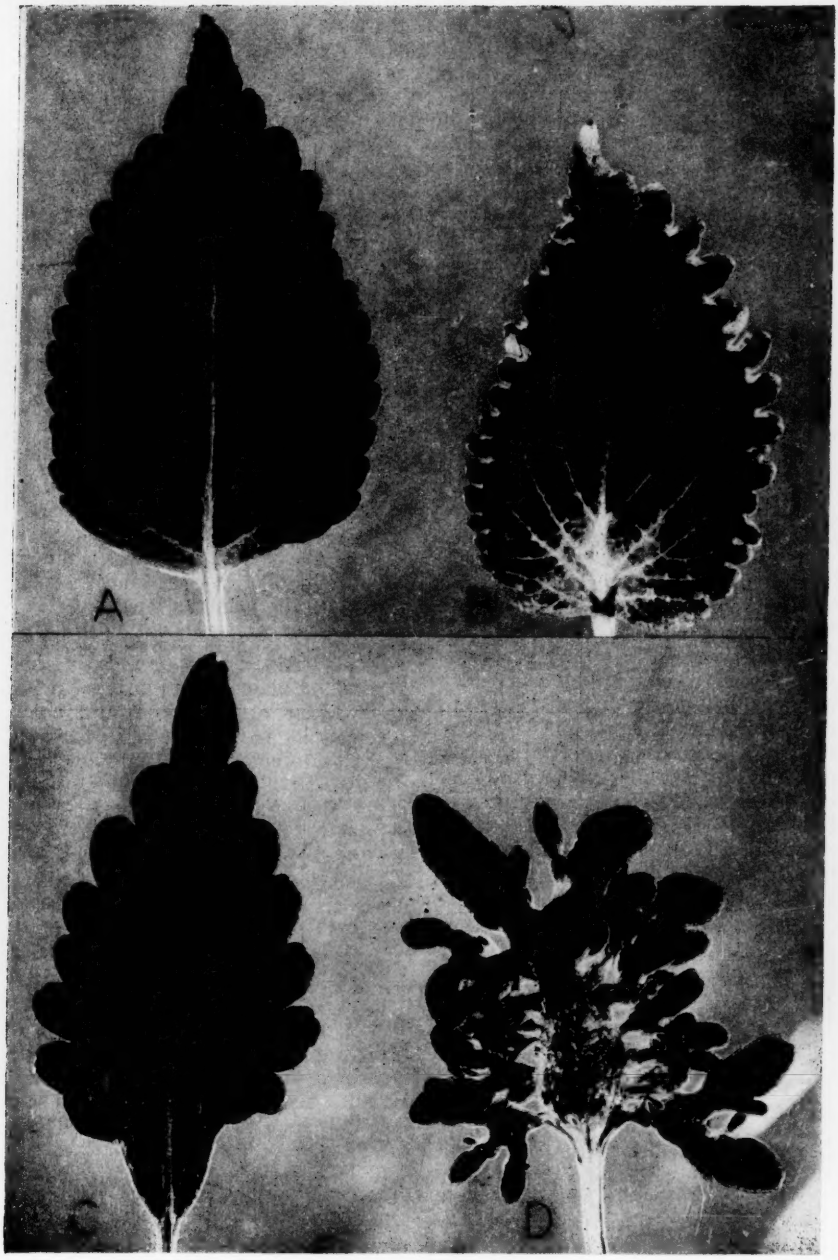
P is between .30 and .05



CHIMERA IN SOMATIC TISSUE

Figure 10

A plant with solid green leaves on one side and patterned leaves on the other. Seeds from both the solid green and the patterned portions of the plant produced offspring in the ratio of approximately three solid green to one pattern.



GENIC INTERACTION

Figure 11

Variations in shape of coleus leaves due to interaction of two pairs of alleles. *A*—Regular and shallow lobed leaf (*ggll*); *B*—Regular and deep lobed leaf (*ggLL*); *C*—Irregular and shallow lobed leaf (G^-ll); *D*—Irregular and deep lobed (watermelon) leaf (G^-L^-).

branches and from patterned branches. Seed from both kinds of plants produced offspring in the ratio of three solid green to one pattern, indicating that the chimeral mutations occurred only in the somatic tissue.

These chimeras usually occur only in certain strains. We have not observed them in either the Purple or the Trailing Queen clones. Many years ago Stout[9] stated that as much variability appears among coleus propagated asexually as among those raised from seed. Apparently he was working with strains in which chimeras are common.

Polyploids

When seeds are soaked for 24 hours in a 0.5% aqueous solution of colchicine, five to ten per cent of the plants growing from them appeared to be tetraploids. We have produced in this manner tetraploid plants of the pattern, gray and brown strains. The tetraploids have thicker, broader leaves and larger pollen grains than do the diploids. A tetraploid gray plant when self-fertilized produced purple, green, and gray progeny, and in addition a new color combination intermediate between green and gray, designated semi-gray. The phenotypes and genotypes of plants obtained from selfing both diploid and tetraploid gray are as follows:

Diploid		*Tetraploid*	
PP	purple	$PPPP$	purple
Pp^G	gray	$PPPp^G$	
p^Gp^G	green	PPp^Gp^G	gray
		$Pp^Gp^Gp^G$	semi-gray
		$p^Gp^Gp^Gp^G$	green

A new phenotype was obtained from crosses between tetraploid gray ($PPp^Gp^G \times$ diploid pattern (pp). This new phenotype is greenish purple on the upper leaf surface, and has a dark purple pattern on the lower leaf surface. Presumably these plants are completely heterozygous triploids of genotype Pp^Gp. Still another novelty was produced by crossing a diploid purple (PP) with a tetraploid pattern ($pppp$). The progeny resembled pattern plants when quite small but gradually became purple, and at maturity appeared as purple as the purple parent.

Plants of the Trailing Queen variety are usually highly sterile, whether selfed or crossed. After several unsuccessful attempts, three seeds were produced by using pollen from a gray plant (a hybrid between purple and Golden Bedder) to fertilize flowers on a Trailing Queen plant. All the progeny were solid purple plants, but one was a diploid and the other two were polyploids, appearing to have full chromosome complements of both parent strains. The polyploids have extremely dark purple color, thick leaves and grow slowly. Figure 9 shows one of the polyploids, as well as typical plants from Trailing Queen and Purple varieties. Note that the leaf shape of the hybrid resembles Trailing Queen more than Purple, while its color is even darker than the latter.

Discussion

Coleus has unique value as laboratory material. Unlike flowers, leaf pigments are available at any time, and novel combinations may be propagated asexually. Probably no other plant offers such a vast array of leaf color combinations. The alleles of the nine leaf-color genes give us 137,781 distinct genotype combinations, which interact to produce several hundred phenotypic color variations. These numbers may be still further increased by the production of autopolyploids.

The genetic basis for many color variations is yet unsolved. This is especially true of numerous types of spotting and splotching. Plans are now under way to extend the genetic analysis of color variation and to correlate this with biochemical analysis of the pigments involved.

Coleus possesses considerable merit as illustrative material in elementary courses in genetics. Examples of almost all simple types of inheritance may be shown, with the exception of sex linkage. These include simple dominance, blending, lethal factors, pleiotropy, linkage, multiple alleles, male sterility, epistasis and such unusual F_2 ratios as

12:1:2:1, 11:4:1, and 6:3:2:1.

Several difficulties are encountered in the rearing of coleus. The seeds are tiny, and considerable care is required to prevent the seedlings from damping off. Mature plants often become infested with mealy bugs, which are difficult to eradicate. Coleus reproduces rather slowly, nine months to a year being required per generation.

Summary

Thirteen sets of alleles responsible for variations in leaf color, leaf shape, and male sterility in coleus are described. The genes for deep versus shallow leaf lobes and male fertility versus male sterility are very closely linked or belong to the same allelic series. Chimeras occur very rarely in some clones, and with comparatively high frequencies in others. Polyploids may be synthesized by treatment of seeds with colchicine.

Literature Cited

1. Boye, C. L. *Jour. Genet.* 29:55-60. 1938.
2. ————. Unpublished Doctor's dissertation, Ohio State University. 1941.
3. Boye, C. L., and D. C. Rife. *Jour. Hered.* 29:55-66. 1938.
4. Post, Thelma Bennet. *Jour. Hered.* 30:27-31. 1939.
5. Rife, D. C. *Jour. Hered.* 31:293-296. 1940.
6. ————. *Ohio Jour. Sc.* 44:18-24. 1944.
7. ————. *Ohio Jour. Sc.* 45:1-3. 1945.
8. Rife, D. C., and H. C. Duber. *Jour. Hered.* 37:327-330. 1946.
9. Stout, A. B. *Carnegie Instit. Wash., Pub. 218.* Wash., D. C. 1915.

✦

TWO ELEMENTARY GENETICS TEXTS

Genetics Is Easy

TO anyone who has taught genetics it is obvious that some students get it and some do not. This difference is not altogether associated with industry in study or with general intelligence. We have used the expression "genetic I. Q." with a double meaning, indicating ability to solve genetic problems and also that such ability may be hereditary. A single genic difference might account for the discontinuity (or the bimodality) in performance, but the causes of failure in quizzes are doubtless more diverse.

There are, of course, students who do not study and there are those who study conscientiously but in the wrong way and so do not learn after much effort. A block is then built up against a subject that ought to be and often previously had been very fascinating. The teacher's task is to break this block if possible and the title of Goldstein's booklet* may be a first step.

The author teaches biology at the Bronx (N. Y.) High School of Science. This handbook is intended for High School students who should be more plastic than college upper classmen and graduates in whom the block has had more time to solidify. To catch them young and bring them up right should be advantageous. The algebra and geometry studied in High School would appear to be much more difficult and terrifying than most of the genetics taught in beginning courses and certainly than that contained in Goldstein's pages.

The booklet is adorned with many pictures and diagrams and is well written. There are relatively few errors and the author is keen to have suggestions and corrections from readers. In fact the last page is intended to be filled in with comments and returned. This request may furnish a good suggestion to certain writers of more pretentious texts.

One good thing is that so much is left

*Goldstein, Philip. *Genetics is Easy.* A Handbook of Information for Teachers and Pupils. 72 pp. 75 cents. Garlan Publications, 77-79 River Street, Hoboken, N. J. 1947.

out. The fundamentals are emphasized and the most recent developments are given,—genic balance in sex determination, x-radiation effects, chromosome irregularities, biochemical genetics, pigment production, mating types in Paramecium, and human blood groups including Fisher's theory of linked genes within the Rhesus alleles; but there is not too much of any of these. There is no tendency toward hypertrophy of any one aspect, and the author maintains a good balance.

The booklet is not recommended for research investigators. It is written by a teacher and is intended for beginning students.

P. W. WHITING
University of Pennsylvania

✦

Genetics for the Arts Course Student

THE second edition of Colin's *Elements of Genetics** is an ideal introductory text for the arts student. Human interest is aroused by details about the heroes of evolution and genetics: Darwin, Mendel, Morgan and others. It is popularly written, yet considerate of the scientific facts. It reviews the principles of genetics with fitting illustrations drawn from various fields of research; then lists and describes a number of medico-genetic syndromes. There is a description of the relationship of genetics to evolution and to stock improvement. Fortunately, Colin's fellow-Chicagoan, Sewall Wright, checked the book for accuracy, with the result that the deficiencies of the first edition have been remedied and improvements have been made. The illustrative examples lean slightly toward the studies of Wright and Strandskoff with which the author is probably more familiar because of propinquity. There is a glossary of genetic terms.

The reviewer has a feeling that multiple factors should have had a fuller treatment together with illustrative problems on the subject, although some teachers will disagree saying that the average arts student is so lacking in mathematical ability that this facet of genetics should be reserved for the weightier text of the science major.

Since this book is not a compendium of facts but rather an exposition of genetic principles, and will probably be employed by many biology teachers who are not specialists in genetics, it is to be hoped that for the benefit of such teachers Colin will prepare an accompanying key answering completely the 157 good genetic problems found distributed at the ends of most of the chapters.

Because this text will probably be widely used in arts courses, the reviewer would propose that it be accompanied by a work manual, (1) reprinting the same problems given in the text with space for their written answers or detailed calculations. This work manual should contain (2) outside reading references to accompany the chapters, as well as (3) instructions for a series of simple experiments on drosophila, corn, mice, and other readily available materials. These exercises are essential for those classes desiring to use the Colin text as the basis for a laboratory course in genetics.

Genetics is an experimental subject and can best be illustrated by experiment.

CLYDE E. KEELER
Georgia State College for Women, Milledgeville

*COLIN, EDWARD C. *Elements of Genetics*, Second Edition. 402 pages. Blakiston, Philadelphia. 1946.

A NOTE ON IRIS RIM COLOR AND WIDTH

MARIANNE E. BERNSTEIN AND BARBARA S. BURKS

A FIELD worker, collecting family data on the color of the main part of the human iris, at the same time also recorded the color and width of the iris rim of 216 individuals. Rim color falls into nine classes: two shades of blue, six shades of grey and one shade of "very dark." She also observed several cases of "narrow rim" and of "no rim."

If we look at the human eye from the front it may be observed that the main part of the iris is separated from the white coat of the sclera by a narrow, dark rim, called "iris rim" throughout this study. For what they are worth some observations on variations in the color and size of the iris rim, made in connection with another research, are here put on record.

It was found that with every iris color, one specific rim color would be observed more often than all other eight rim shades combined. This rim color was called modal rim color throughout this study; any deviations from it were classified as lighter or darker than the mode. The darker the iris, the darker was also the modal rim color, which may explain why parents with rim colors darker than the mode were found never to have offspring with rim color lighter than the mode, for here we are dealing with persons having light eyes. A similar situation held for parents with rim colors lighter than the mode; they had no offspring whose rim color was darker than the mode.

Results

The percentage of modal rim color was found to be about the same for five different age classes and for the two sexes; age and sex apparently do not upset the relationship between the color of the iris rim and the main part of the iris.

It was found that 169 of the 216 persons examined had modal rim colors or 78.61% ± 2.8%. In the nine families where both parents had modal rim colors, 36 of their 44 children or 81.8% ± 5.8% had modal rim colors. In 4 families one parent had modal, the other parent non-modal rim color; and in 4 other families where one parent was deceased, the surviving parent had non-modal rim color. In these eight families 17 out of the 25 children or 68.0% ± 9.4% had modal rim colors.

The difference of 13.8% between the incidence of modal rim color in the two types of families is only 1.15 times as large as its standard error of 11.1% and the difference may therefore be due to chance. Since it is in the "right" direction, however, a larger set of data may prove this difference to be a true one.

The trait of narrow rim was also found to run in families; more offspring had narrow rims if one of their parents was thus affected than if both their parents had rims of normal size. The difference of 24.13% was 2.23 times its standard error. Two out of the three children in the only family where both parents had narrow rim also were thus affected.

"No rim" was observed only five times altogether; in one family the father was affected and two of his five children had no iris rim; a third child in the same family had a narrow rim.

Conclusions

In the great majority of cases (78.6%) it was found that the color of the main part of the iris prescribed the shade of the rim of the iris, called modal rim color. Deviations from this modal color were found to run in families, though the data were not extensive enough to yield differences which were reliable statistically. The data yielded evidence of the existence of genes determining the presence and size of the iris rim. But more of data are needed to determine the Mendelian transmission of these traits and their possible linkage.

*M. Bernstein is at Syracuse University. The late Dr. Burks was in the Department of Genetics, Carnegie Institution of Washington, Cold Spring Harbor.

WHITE-BELLIED HOUSE MICE

On Some North Carolina Coastal Islands

WILLIAM L. ENGELS

Department of Zoology, University of North Carolina

WHEN my field studies of the vertebrate fauna of the North Carolina coastal islands were begun in 1938, it was immediately discovered, rather surprisingly, that the small mammals were represented on Bogue Banks almost exclusively by "house" mice, *Mus musculus*. These mice, in considerable numbers, inhabited the Uniola ("sea-oats") association forming the vegetational cover in the dunes area. It was noted at the time that some of the mice had clear white bellies, reminiscent of the white-footed mice (*Peromyscus*), but the relative number of these was not recorded. Later we found a population in a similar habitat on Ocracoke Island that consisted predominantly of white-bellied mice, one sample containing only 3 gray-bellied mice out of 23 collected[2]. It then became a matter of special interest to determine (1) the genetic basis of white-belly in these particular natural populations, and (2) the relative frequencies of the genes involved.

Accordingly, opportunity was taken during the Christmas holidays of 1946 to revisit Bogue Banks,* to collect some of the house mice for test matings. Thirty mice were caught during two nights, using some 80 live-traps, and carried back to the laboratory in small individual carriers made of bronze screening. All the females were kept isolated for a period of four weeks to segregate possible pregnancies by unknown males. During this period, and beginning immediately on return to the laboratory, many of the mice died from some disease apparently of an epidemic nature. Of the 30 mice caught on Bogue Banks, 12 were white-bellied; and of these, 5 were lost in the epidemic. The remaining 7 were isolated each with a gray-bellied mate, after the segregation period of four weeks. Each of the gray-bellied individuals also was from the sample collected on Bogue Banks.

The pairings were made during the first week of January 1947. When after 10 weeks no litters had appeared, exercise wheels were placed in the cages[7] and these were used by the mice immediately and intensively. Subsequently 18 litters were produced, but it is uncertain whether the exercise wheels deserve chief credit; the consequent sexual activity may have been due to a seasonal periodicity.

Results of the Matings

(1) Of the six wild-caught white-bellied mice successfully tested with gray-bellied mates, one produced apparently only white-bellied offspring. The second litter of white-bellied female No. 11 was destroyed before either their number or phenotypes were determined, but one previous and three subsequent litters from this female, sired by a gray-bellied male, totalled 20 mice, none of which was gray-bellied. Unfortunately, no F_1 matings were made from these litters, but the evidence clearly indicates the dominance of white-belly over gray-belly.

(2) Further evidence of the dominance of white-belly is afforded by two white-belly × white-belly matings, involving one wild-caught mouse and three cage-bred mice of white-belly ×

*Special acknowledgment is due my colleague, Dr. C. S. Jones, who during the summer months, took charge of the mice, identified the phenotypes and kept the records; to the U. S. Fish and Wildlife Service for dormitory facilities at its Biological Laboratory, Beaufort, N. C., Dr. H. F. Prytherch, Director; and to Letitia Emery Engels, who assisted in the field work.

gray-belly parentage. The resulting three litters each contained both phenotypes; there was a total of 9 white-bellied and 6 gray-bellied offspring. Chi-square for the observed deviation from the expected 3:1 ratio is 1.80, a sufficiently satisfactory fit.

(3) Six white-bellied mice, each with a gray-bellied mate, produced a total of 47 offspring in 8 litters. Of the 47 progeny, 28 were white-bellied and 19 gray-bellied; both phenotypes appeared in each litter but one, which consisted of 4 gray-bellied mice. Assuming dominance of white-belly and a single Mendelian factor, white- and gray-bellied offspring were expected in equal numbers. Chi-square for the observed deviation from this 1:1 ratio is 1.72, a sufficiently satisfactory fit.

The above evidence identifies the gene involved as A^w, the dominant "white-belly agouti" allelomorph of "agouti." White-bellied agoutis have been reported a number of times as occurring in natural populations (Grueneberg 1943, pp. 30-31) and at least 13 supposed mutations to white-belly have been reported from laboratories[5]. The mice of St. Kilda island were found to be exclusively white-belly agoutis[1] and hence presumably all homozygotes. The only other report on relative numbers of the pheno- and genotypes in wild populations is that of Philip[6] who found only homozygotes among the white-bellied and gray-bellied mice from some Scottish coal-pits. Despite the small number of specimens (3 white-bellied mice) she interpreted the data to indicate absence of random mating between the two phenotypes, and suggested an ecological segregation as the isolating factor. So it is of interest to test the sample population from Bogue Banks, North Carolina, for evidence of inbreeding, or the lack of it, in the mating system.

Random Mating

The statistical method used to determine the gene frequencies and the mating system is that developed by Haldane[4] in a paper accompanying that of Philip. In the sample from Bogue Banks, the ratio in numbers of the dominant to the recessive gene, $A^w : A+$, proved to be 0.298. There is then calculated the relative numbers of *a*) the dominant and *b*) the recessive phenotypes expected from this gene ratio in a system of random mating, as well as the expected numbers of *c*) homozygotes and *d*) heterozygotes among the dominant phenotypes. The observed deviations from the expected numbers may then be tested by the chi-square test of significance. The results follow:

	a	*b*	*c*	*d*
observed	12	18	1	5
expected	12.20	17.80	0.78	5.22
chi-square	0.0033	0.0022	0.0621	0.0093

Chi-square over the whole table is thus (summed) 0.077, and the fit to a system of random mating is exceptionally good. Of course, the sample is a small one, and it may be questioned (1) that the relative numbers of the two phenotypes in the sample collected reflect closely their true proportions within the whole population of the island and (2) that the heavy mortality suffered by the mice during the first two weeks in the laboratory took a balanced toll of the two classes of dominant phenotypes. However, a random mating system was rather to be expected, especially since no obvious ecological segregation between the two phenotypes was observed in the field. The seeming lack of random mating in the mixed population studied by Philip must be considered an exceptional case.

Summary

White-bellied house mice occur in considerable numbers together with typical gray-bellied mice on at least two of the islands in the chain forming the North Carolina "outer banks." Mating tests with mice from Bogue Banks identify the gene as "white-belly agouti", A^w. In a sample of 30 mice from this island the ratio in numbers of the two genes, $A^w : A+$, was 0.298. Statistical analysis indicates that in the natural population mating between the two phenotypes is at random.

Literature Cited

1. CLARKE, W. E. *Scottish Naturalist*, pp. 124-128. 1914.
2. ENGELS, W. L. *Amer. Midl. Nat.* 28: 273-304. 1942.
3. GRUENEBERG, H. *The Genetics of the Mouse. vi* + 412 pp. Cambridge: University Press. 1943.
4. HALDANE, J. B. S. *J. Genet.* 36:213-220. 1938.
5. KEELER, C. E. *Proc. Nat. Acad. Sci.* 17: 700-703. 1931.
6. PHILIP, U. *J. Genet.* 36:197-211. 1938.
7. SCHNEIDER, H. A. *Proc. Soc. Exp. Biol. and Med.* 63:161-165. 1946.

✦

SCIENCE CYCLOPEDIA

ONE can get a broad but kaleidoscopic grounding in science by reading the *Encyclopedia Brittanica.* In the process one would become somewhat heterogeneously educated in other fields of human endeavor, too. However, so dizzifying have the complexities of this specialized world of ours become that it is no longer feasible to attempt to enclose within the compass of a single work the "full circle of arts and sciences." Even the Encyclopedias are shifting to a more concentrated pabulum covering more limited areas. *Van Nostrand's Scientific Encyclopedia** packs into exactly 1600 pages an astonishingly varied collection of odds and ends about what we call science, which begins with "A supply" and ends with "zygote." Radio fans will have to go elsewhere to find out what "kilocycle" means.

The biological references are competently handled under the contributing editorships of Professor A. W. Lindsey of Denison University and Professor Bernard S. Meyer of Ohio State University.

If we look for "genetics," we are referred to "heredity," where in just a little over two pages we are briefed on Mendelism and recent developments. This discussion is in the main excellent. A few points might be questioned. The discussion of unit characters and alleles is confusing, and could be interpreted to include epistasis. The statement that "The study of human heredity depends entirely on observation of the family, since controlled mating is impossible" is no longer strictly true, for within the last decade the principles of population genetics have to some extent freed the study of human heredity from simple pedigree analysis and opened up novel approaches to the study of human genetics. In general the newer biometrical approaches, as they apply either in the study of genetics or in the development of newer theories of evolution, tend to be ignored. But then we can't expect everything in 1600 pages.

Science in the popular mind is predominently physics and chemistry. This book seems to maintain an excellent balance between the life-sciences and the matter-sciences. This very useful volume will undoubtedly become a standard reference work in every well-equipped library—R. C.

**Van Nostrand's Scientific Encyclopedia.* Second Edition. 1600 pp. $12.00. New York, 1947.

UNIFORM - RELIABLE - NUTRITIOUS

Dickinson's Globe Feeds are all of the above . . . and more. They have proven worthy as dependable food products for many years, and enjoy wide usage and acceptance among laboratories raising small experimental animals.

These popular Globe Feeds come in dry form—pellets, nuggets, meal, for ease of feeding and economy in use. Boxes below show suggested types of feed for various animals.

FOR RABBITS	FOR RATS AND MICE	FOR GUINEA PIGS
Globe Rabbit Glob-ets to be supplemented with hay. Globe Rabbit with Alfalfa, pellet form—complete.	Dickinson's Dog Food — Nugget—Pellet or meal form. Dickinson's Kibbled Dog Food.	Globe Rabbit Glob-ets to be supplemented with hay. Globe Rabbit with Alfalfa, pellet form—complete. Supplement with Vitamin C carrier three times a week.

GENEROUS SAMPLES FREE

To supervisors of experimental animals, we will send a free sample, large enough to make an adequate test. Just tell us the kind and quantity of food desired.

THE ALBERT DICKINSON COMPANY

2714 WEST 35TH STREET CHICAGO 32, ILLINOIS

COMMONWEALTH AGRICULTURAL BUREAUX

The abstracting and reviewing journals of the two Institutes and ten Bureaux in this organization cover the world literature on all aspects of crop and animal breeding and husbandry. Four journals are of special interest to geneticists.

PLANT BREEDING ABSTRACTS. Quarterly, covering the breeding, genetics and cytology of all economic crops. ANN. SUB. $7.00

ANIMAL BREEDING ABSTRACTS. Quarterly, covering the breeding of domestic animals, fur bearers, rodents and poultry, and literature on reproduction. ANN. SUB. $7.00

HORTICULTURAL ABSTRACTS. Quarterly, covering the cultivation of deciduous tree fruits, small fruits, vegetable, tobacco and other plants, tropical and subtropical plantation crops. ANN. SUB. $7.00

FIELD CROP ABSTRACTS. Commencing publication January, 1948, appears 6 times per annum, and covers the cultivation and agricultural botany of all crops grown in field rotations. ANN. SUB. $7.00

TECHNICAL COMMUNICATIONS.	Price
Five hundred varieties of herbage and fodder plants. March, 1948.	$3.00
The new genetics in the Soviet Union.	$1.25
The semen of animals and its use for artificial insemination.	$1.50

These Publications may be ordered from:

AMERICAN GENETIC ASSOCIATION
1507 M Street, N. W., Washington 5, D. C.

The next time you hear voices —LISTEN!

IT MAY BE your conscience speaking.

It may be saying: "Save some of that money, mister. Your future depends on it!"

Listen closely next time. Those are words of wisdom. Your future—and that of your family—*does* depend on the money you put aside in savings.

Do this: start *now* on the road to *automatic* saving by signing up on your company's Payroll Savings Plan for the purchase of U. S. Savings Bonds.

There's no better, no surer way to save money. Surer because it's automatic . . . better because it pays you back four dollars for every three you invest.

Do it *now*. If you can't join the Payroll Savings Plan, enroll in the Bond-A-Month Plan through your checking account.

Automatic saving is sure saving — U.S. Savings Bonds